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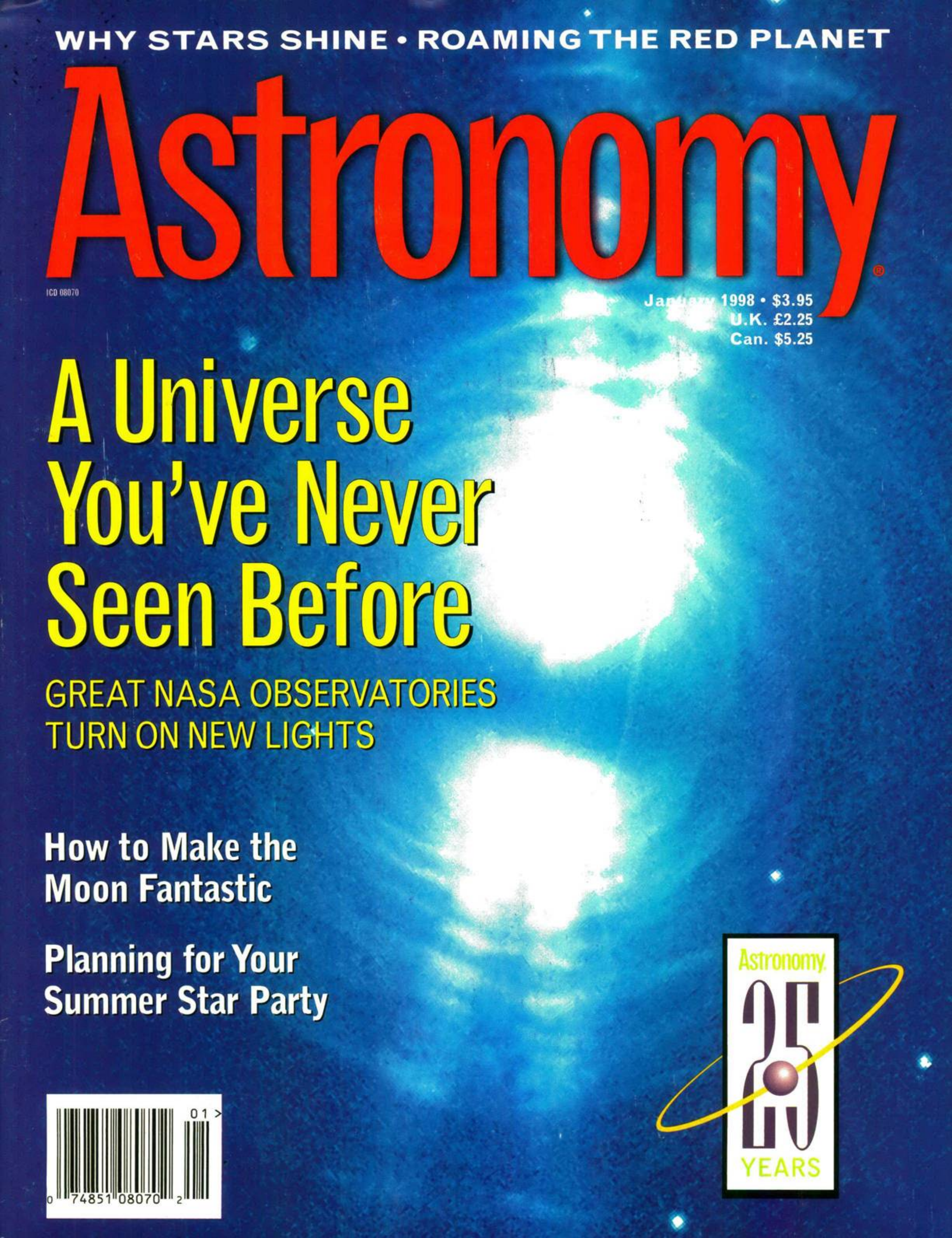

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LX50

Advanced technology at the most affordable prices *ever.*

■ **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

■ **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

■ **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

■ **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

■ **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

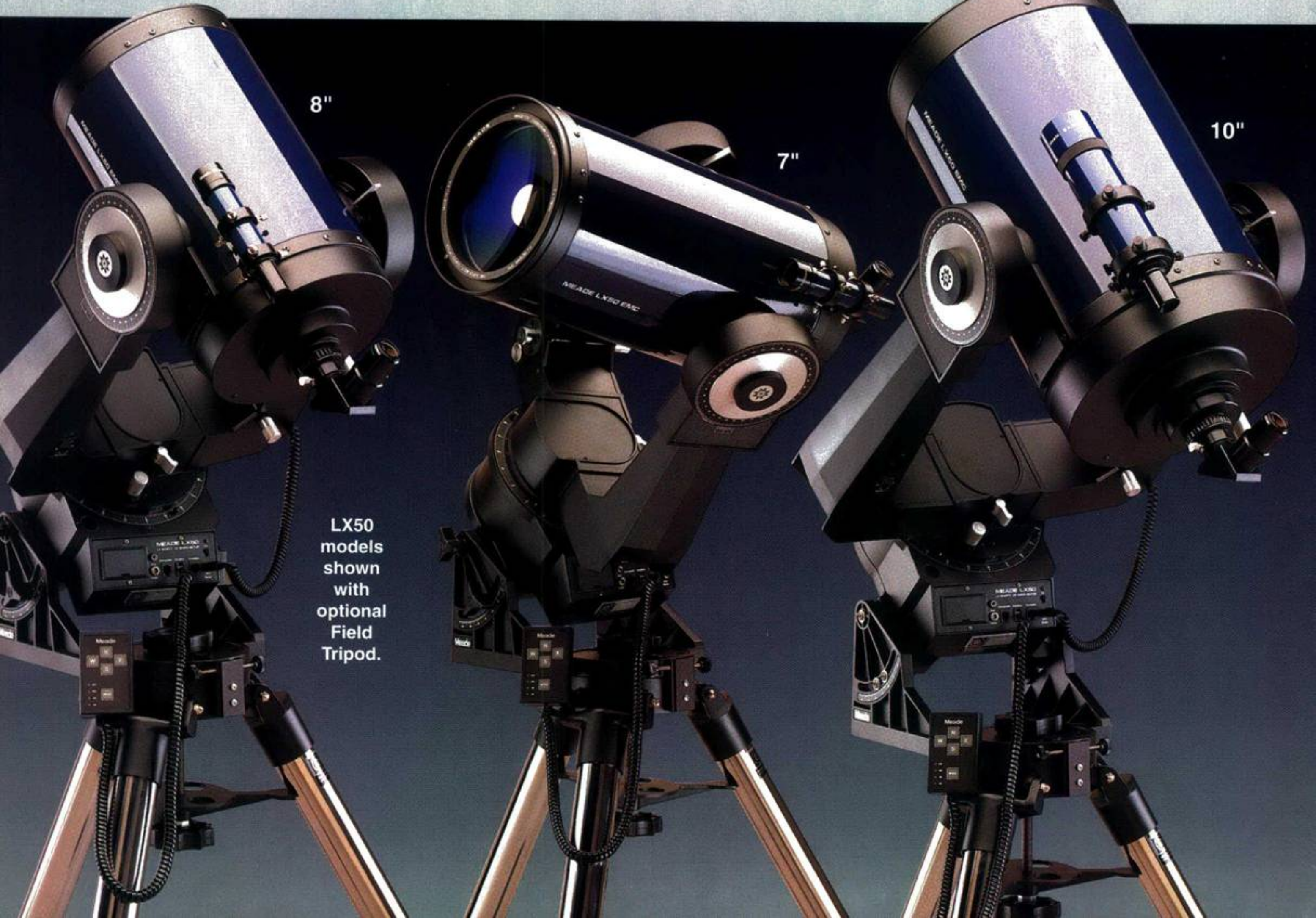
8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y	**1295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

only $495!

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.



LX50 models shown with optional Field Tripod.

ADE
MEADE LX200 EMC
8"
7"
10"
12"

The largest-selling serious telescopes in the world.

LX200

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. Consider these *standard-equipment* specifications:

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

- **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

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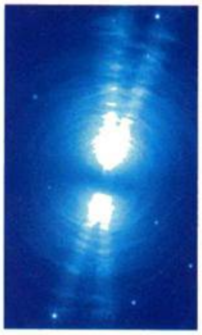

COVER PHOTO: R. Sahai and J. Trauger (JPL) and NASA

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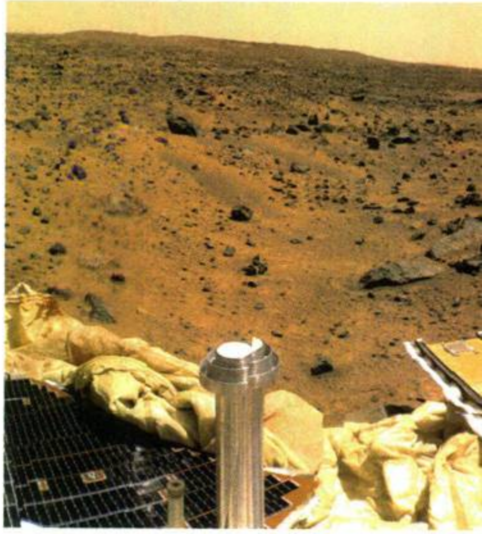

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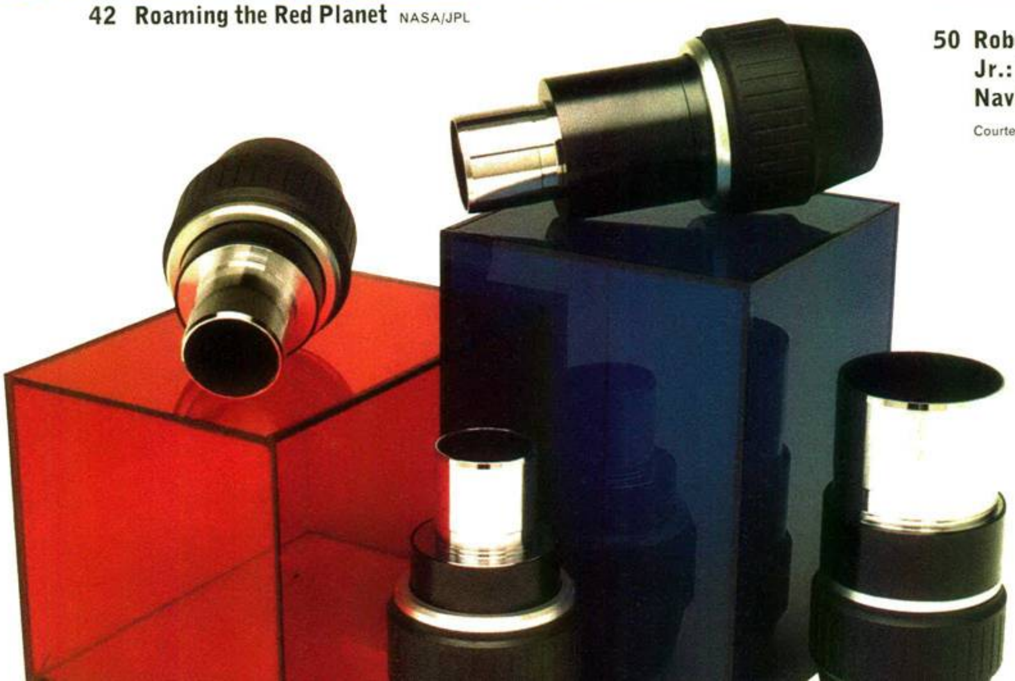
Courtesy of Viola Courtney



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Astronomy: Jim Forbes

BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Astronomy's 25th Year Celebrates You

We're in a generally festive mood around here this year — in the midst of planning our 25th anniversary year — and we have what we believe are dazzling treats in store for readers in 1998. Our biggest surprise begins with this invitation: Come to New Mexico and be our guests at *Astronomy* magazine's Very Own Star Party on June 25, 1998, directly preceding Universe '98, sponsored by the Astronomical Society of the Pacific and cosponsored by *Astronomy.* The party will be free to everyone. It will be held in Rio Rancho Balloon Fiesta Park, an easy drive from Albuquerque. The Albuquerque Astronomical Society will co-sponsor the party, and that's a job they do well. The same group brought 13,000 people to Rio Rancho for a spring party in 1997 to watch Comet Hale-Bopp. We will also have helping hands from the University of New Mexico Institute for Astrophysics and the City of Rio Rancho Parks and Recreation Department. This party will include views of a notoriously clear sky, a wealth of entertainment for young astronomers and their families, a beginners' corner, and a panel where you may question the editors of *Astronomy* on (most) anything you want. Advance copies of our celebration August 1998 issue should be in our hands for the party. (See page 90, "Take Me to a Star Party.")

Jerry Cotey

Celebrate *Astronomy*'s 25th birthday — party in June under the stars in New Mexico.

In this issue of *Astronomy,* we are launching a series of contests that invite your participation. (See page 32, "Come Play With Us.") We're looking for writers, thinkers, and photographers who want to appear in our pages. Share your observing stories — and argue intriguing scientific and philosophical topics. Show off your best photography. We also are welcoming the photos, drawings, and stories of the next generation of astronomers — in a kid's corner. To celebrate our anniversary, we hope to entice you to come all the way into our pages.

If you decide not to play any of these games, we'll forgive you. We'll still give you the riches of astronomy — the past, the present, the future. Our anniversary issue will be substantially bigger than usual and offer you a whole range of topics, including one that will flirt with the future of astronomy. This month, we will gather together a group of talented scientists who will talk to us about the next 25 years of discovery.

All year long, we'll present an unmatched array of subjects, writers, photos, artwork, and cartoons. We'll take you along on interplanetary missions. We'll delve into mysteries that touch on the beginnings of the universe. We'll bring you knowledge and joy. To celebrate 25 years of publishing about the sky, we will give you an even better *Astronomy.*

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Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Editorial phone: (414) 796-8776; advertising: (800) 558-1544; customer service: (800) 446-5489; subscriptions: (800) 533-6644, 7 days a week, 24 hours a day; fax (414) 796-0126.
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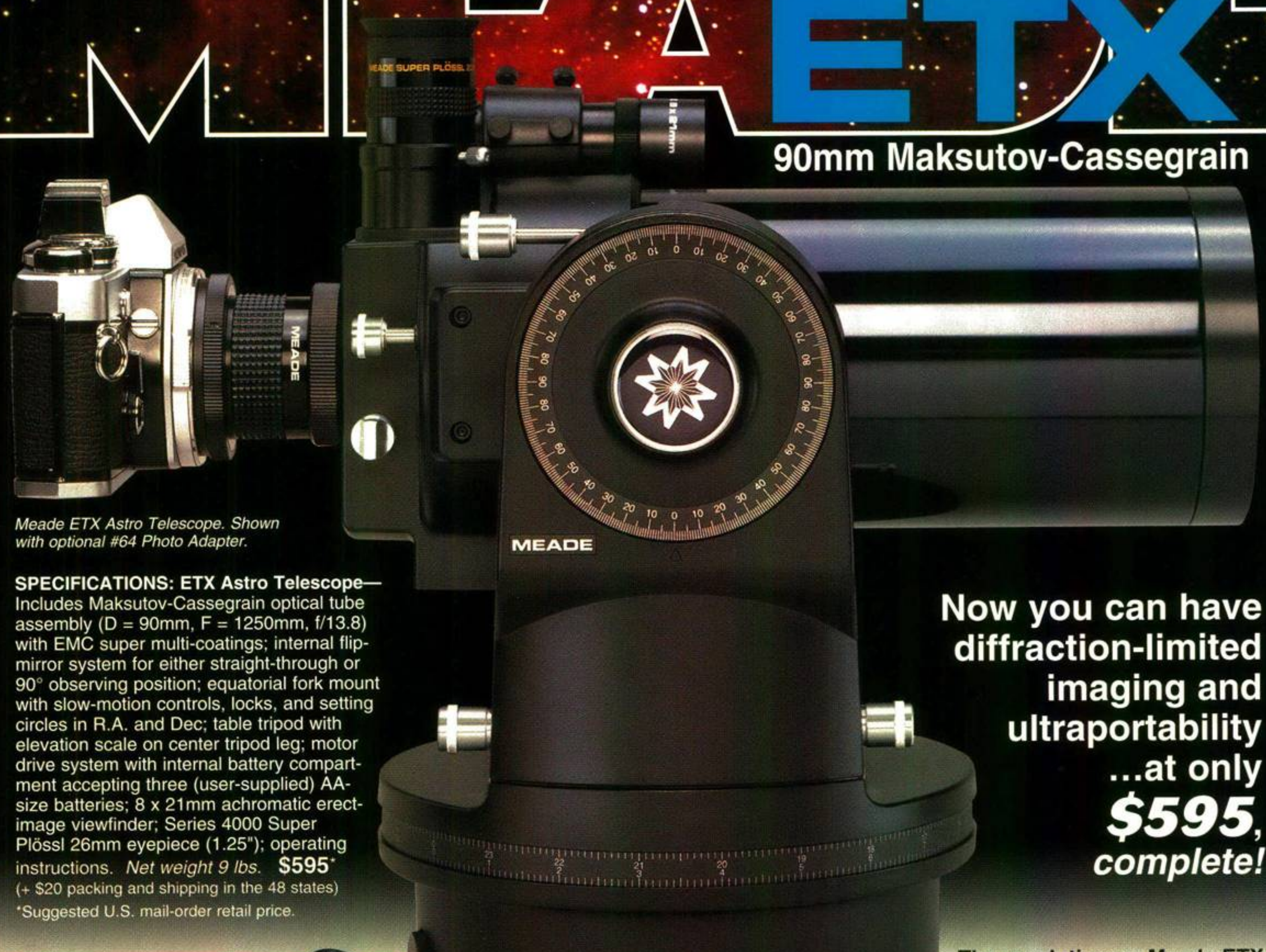
Periodicals postage paid at Waukesha, WI, and additional offices. Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Subscription price: 1 year $34.95, Canadian and foreign: 1 year $45, payable in U.S. funds (Canadian price includes GST). BN 12271 3209 RT. Canadian International Publications Mail Products Agreement 545-775. Not responsible for unsolicited materials. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612.

MEADE ETX

90mm Maksutov-Cassegrain



Meade ETX Astro Telescope. Shown with optional #64 Photo Adapter.

SPECIFICATIONS: ETX Astro Telescope— Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. *Net weight 9 lbs.* **$595***
(+ $20 packing and shipping in the 48 states)
*Suggested U.S. mail-order retail price.

Now you can have diffraction-limited imaging and ultraportability ...at only *$595*, *complete!*

The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds,* just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.

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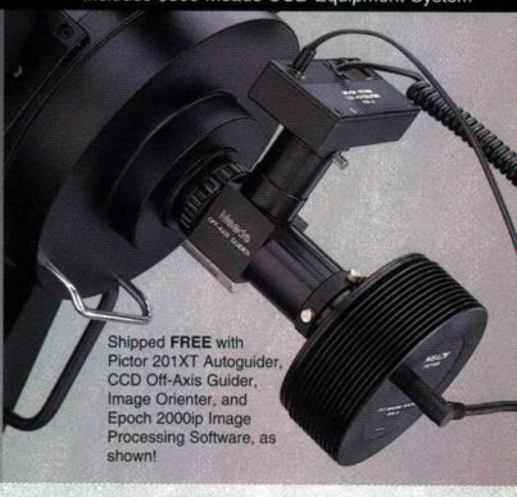
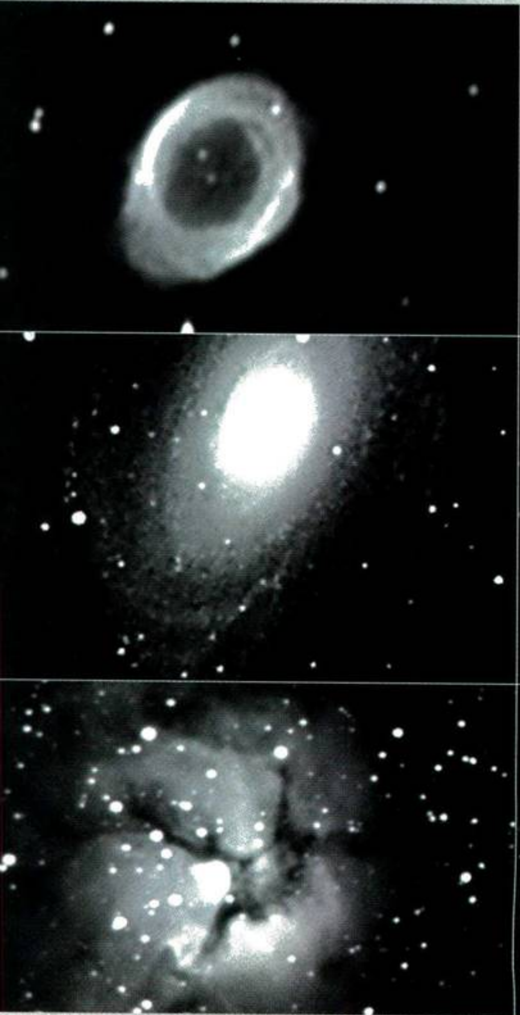
includes $800 Meade CCD Equipment System

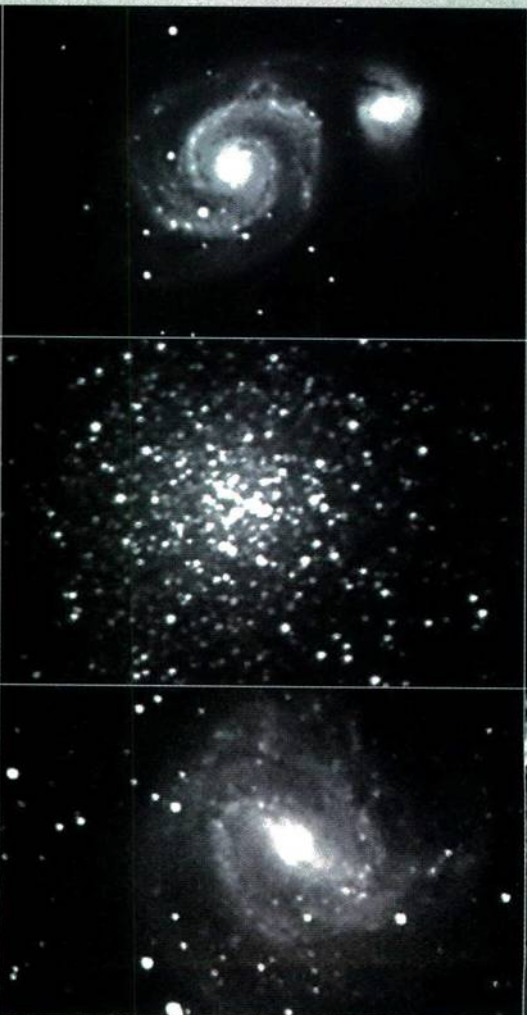


Shipped **FREE** with Pictor 201XT Autoguider, CCD Off-Axis Guider, Image Orienter, and Epoch 2000ip Image Processing Software, as shown!

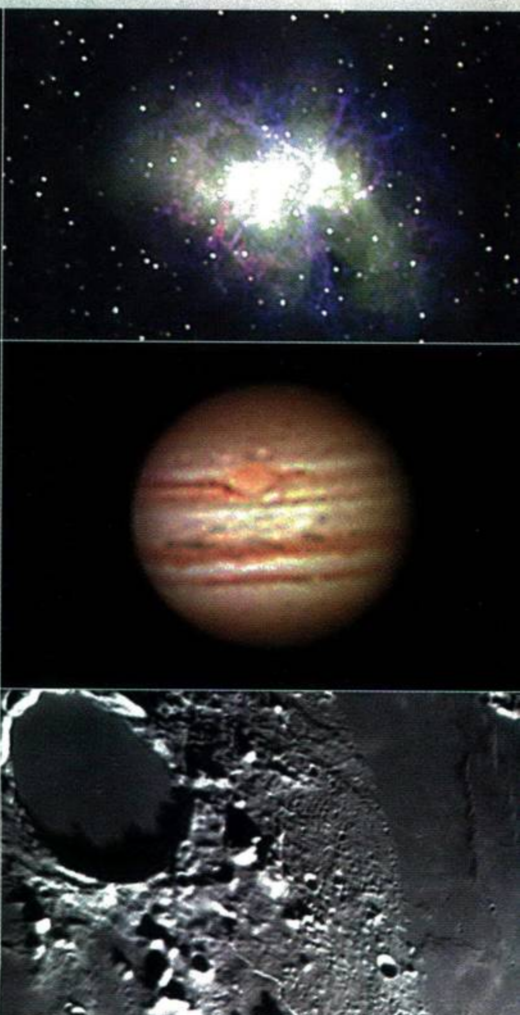
Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only **$495** the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets, or, in 2 or 3 minutes, of thousands of deep-space objects. At **$695** the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-$1000. At **$1695** the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes. All models are available for immediate shipment. ***For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 100-page Meade General Catalog.***



Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.



Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.



Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker.

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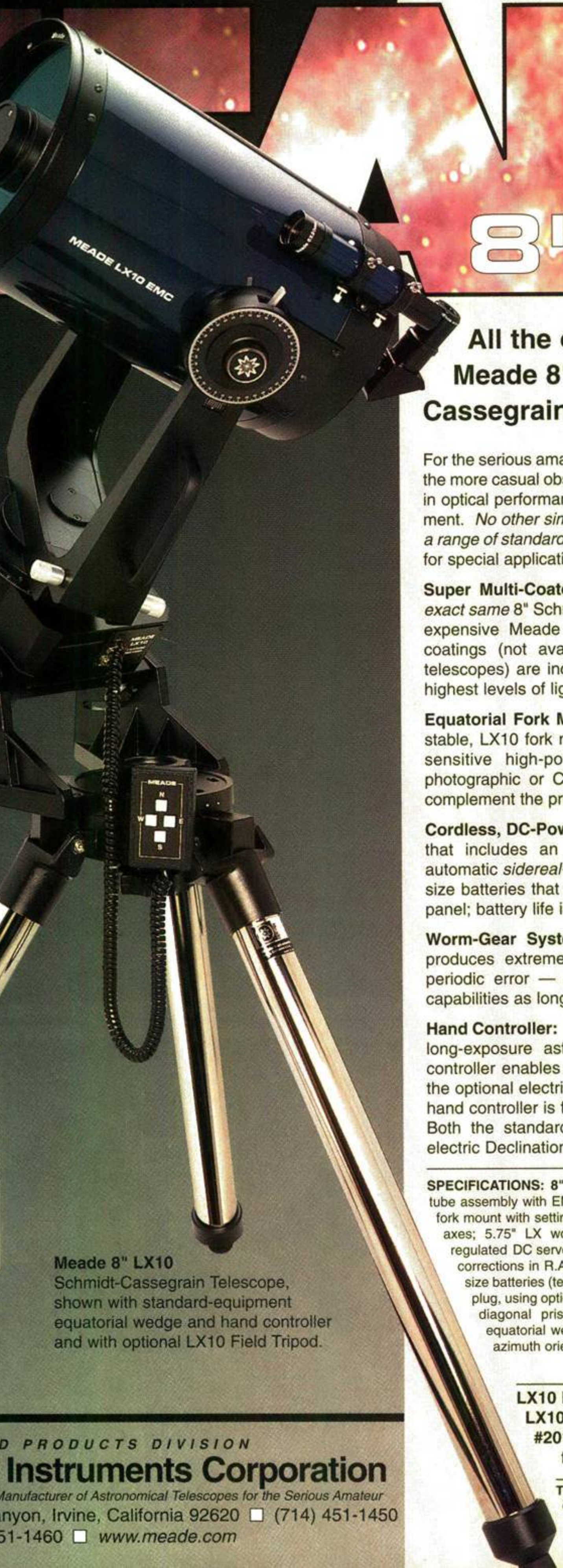
MEADE 8" LX10



All the optical performance of Meade 8" LX50 and LX200 Schmidt Cassegrains...for only *$995!*

For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *No other similarly-priced 8" Schmidt-Cassegrain offers such a range of standard features* — or such a range of important options for special applications. *Standard-equipment includes:*

Super Multi-Coated Optical System: The LX10 includes the *exact same* 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. Super multi-coatings (not available even as an *option* on competing 8" telescopes) are included with every LX10 optical system, for the highest levels of light transmission and image contrast.

Equatorial Fork Mounting: The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. Ball bearings on the polar axis complement the precise action of the internal worm gear system.

Cordless, DC-Powered Electronic Motor Drive: A drive system that includes an electronically-regulated DC servo motor for automatic *sidereal-rate* tracking. The drive is powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours.

Worm-Gear System: The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging.

Hand Controller: Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes. Both the standard-equipment hand controller and the optional electric Declination motor plug into the telescope's control panel.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions.

$995. (+ $65 packing & shipping in the 48 states)

LX10 Field Tripod	**195.**
LX10 Electric Declination Motor System	**85.**
#2014 Magellan I Telescope Computer System for LX10, with 12,218-object database	**375.**

The 100-page Meade General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers. Prices shown are suggested U.S. mail-order prices.

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Add the optional LX10 Declination Motor for dual-axis corrections at 2x.

Meade 8" LX10
Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

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MEADE STARFINDER DOBSONIANS

No other competing Dobsonians include this listing of *standard-equipment* features:

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

1 - **Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*

1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*

3 - **Meade MA9mm, 12mm, and 25mm** multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. *(reg. $37.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $223.75!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

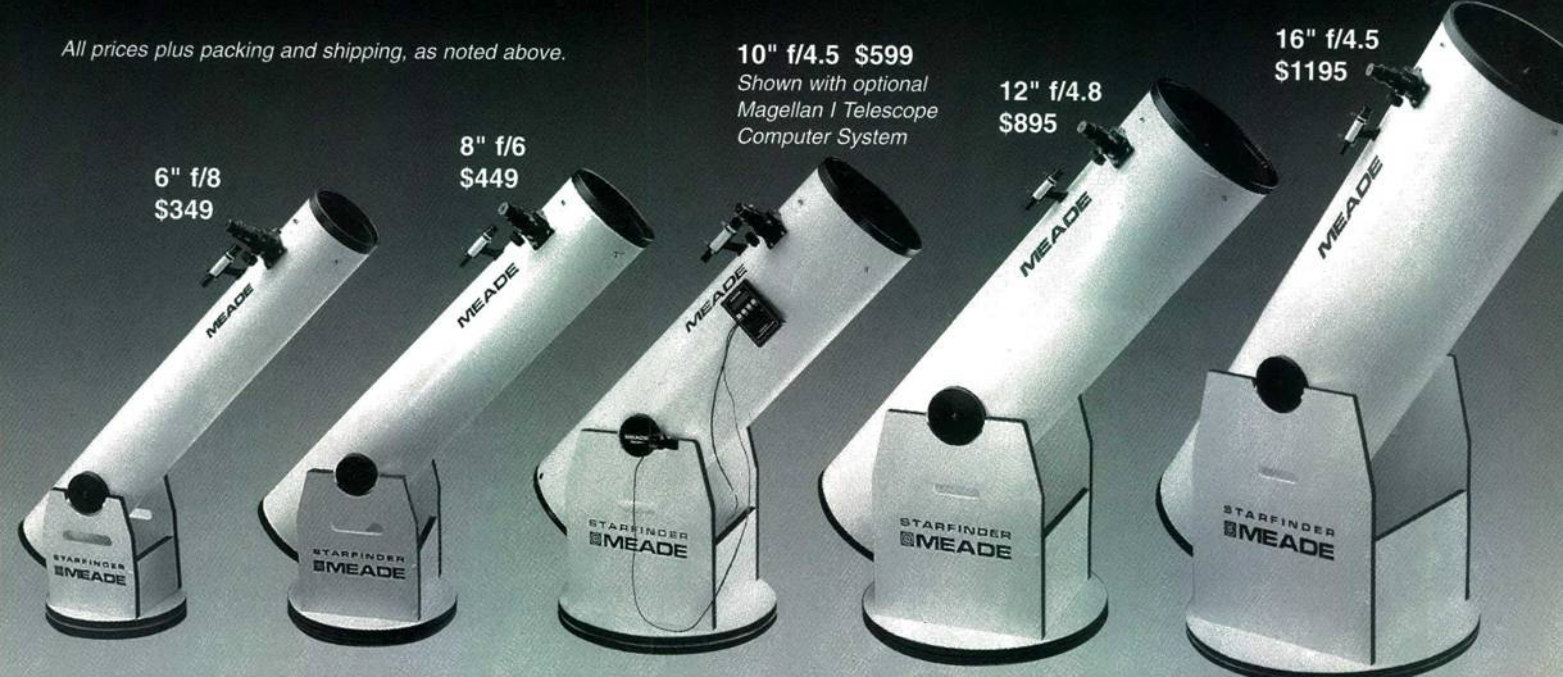
MEADE
ENTER
MODE
PREV
NEXT
ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***

All prices plus packing and shipping, as noted above.



6" f/8
$349

8" f/6
$449

10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12" f/4.8
$895

16" f/4.5
$1195

MEADE
STARFINDER EQUATORIALS

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, ***for a total of $29.95!*** *Purchased separately, the 2 eyepieces sell for $75.90.*

The fullest exposition of Meade astronomical telescopes, CCD imagers, and telescope accessories is contained in the 100-page Meade General Catalog.

Write, call, or fax Meade Instruments for your free copy!

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16". . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

To Order: Contact your authorized Meade Advanced Products Mail-Order Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 717-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:
EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur
6001 Oak Canyon, Irvine, California 92620 ☐ (714) 451-1450
FAX: (714) 451-1460 ☐ *www.meade.com*
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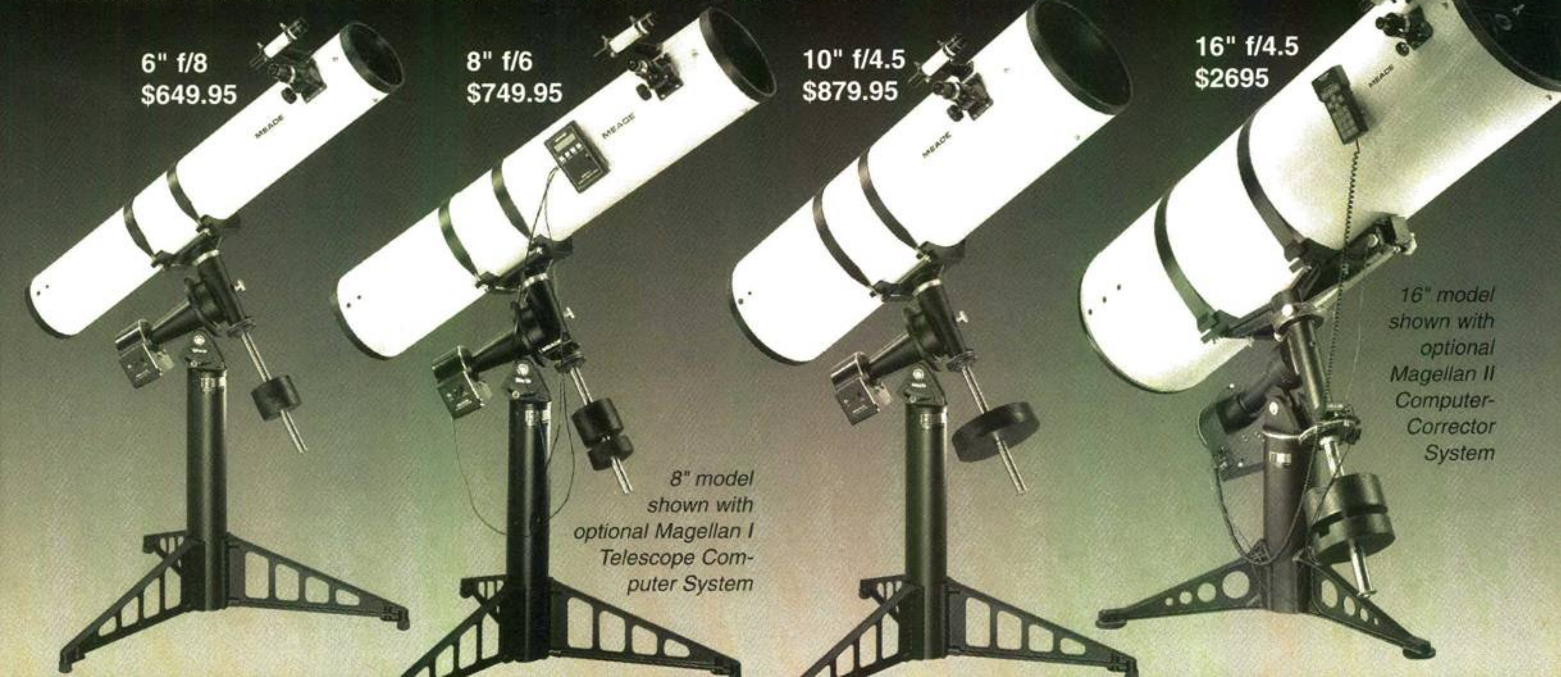
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***

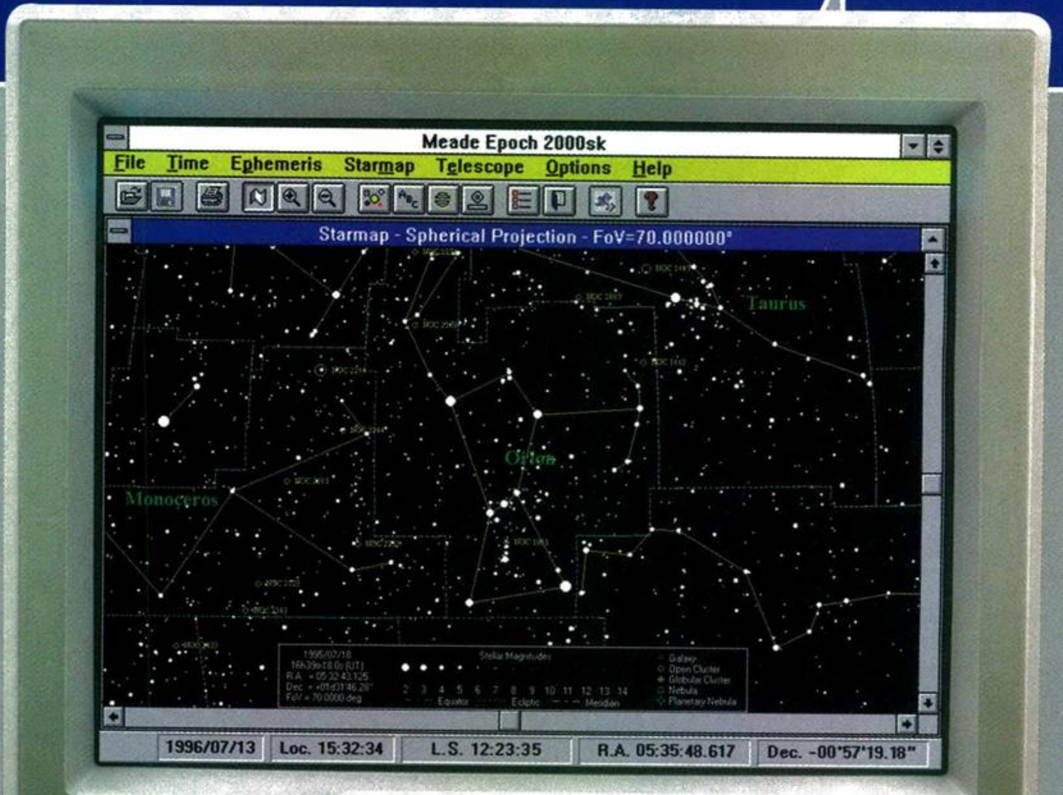


8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

MEADE

EPOCH 2000® SKY SOFTWARE

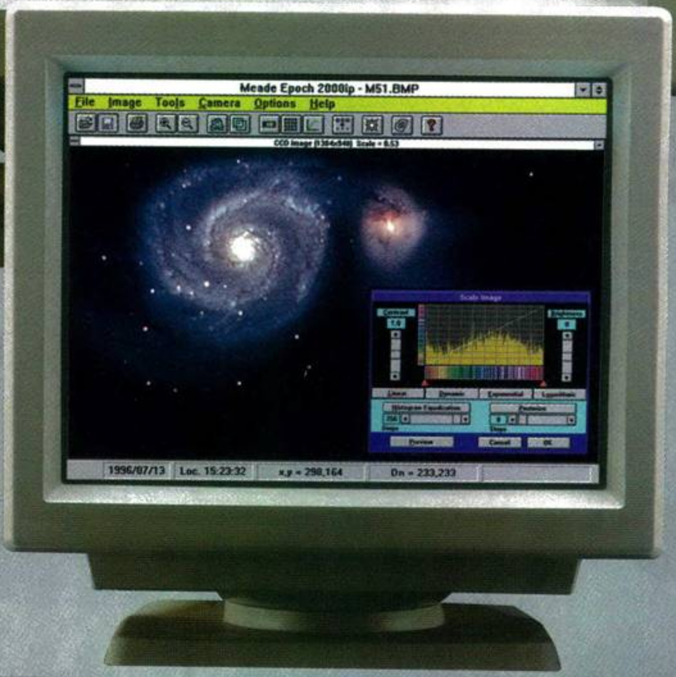

Meade Epoch 2000sk
File Time Ephemeris Starmap Telescope Options Help
Starmap - Spherical Projection - FoV=70.000000°
Taurus
Orion
Monoceros
1996/07/13
Loc. 15:32:34
L.S. 12:23:35
R.A. 05:35:48.617
Dec. -00°57'19.18"

The most powerful astronomical software ever made available can now be yours for only $149!

Now you can use the most advanced, most precise sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** no longer is the Trapezium in Orion, for example, shown as a single point as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professsional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Send for your free copy of the 100-page Meade General Catalog. See why, if you're serious about astronomy, Meade Epoch 2000sk is the only sky software to use!


Meade Epoch 2000ip - M51.BMP
File Image Tools Camera Options Help
1996/07/13
Loc. 15:23:32
x,y = 298,164
Dn = 233,233

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 **$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

Epoch 2000ip Image Processing Software: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 **$199**

ADVANCED PRODUCTS DIVISION
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World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur
6001 Oak Canyon, Irvine, California 92620 ☐ (714) 451-1450
FAX: (714) 451-1460 ☐ *www.meade.com*
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MEADE

EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™
2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (4.27)

Series 4000™
Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 4000™
Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

Series 4000™
f/6.3 Focal Reducer/ Field Flattener

f/6.3 FOCAL REDUCER/FIELD

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930**, each: **$99.95** (5.87)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.45)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**, 1.25": **$29.95** (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

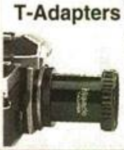
$39.95 (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's



Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

Series 3000™ Plössls
50° field; multi-coated

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, **multi-coated.** Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

$79.95 (3.79)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 717-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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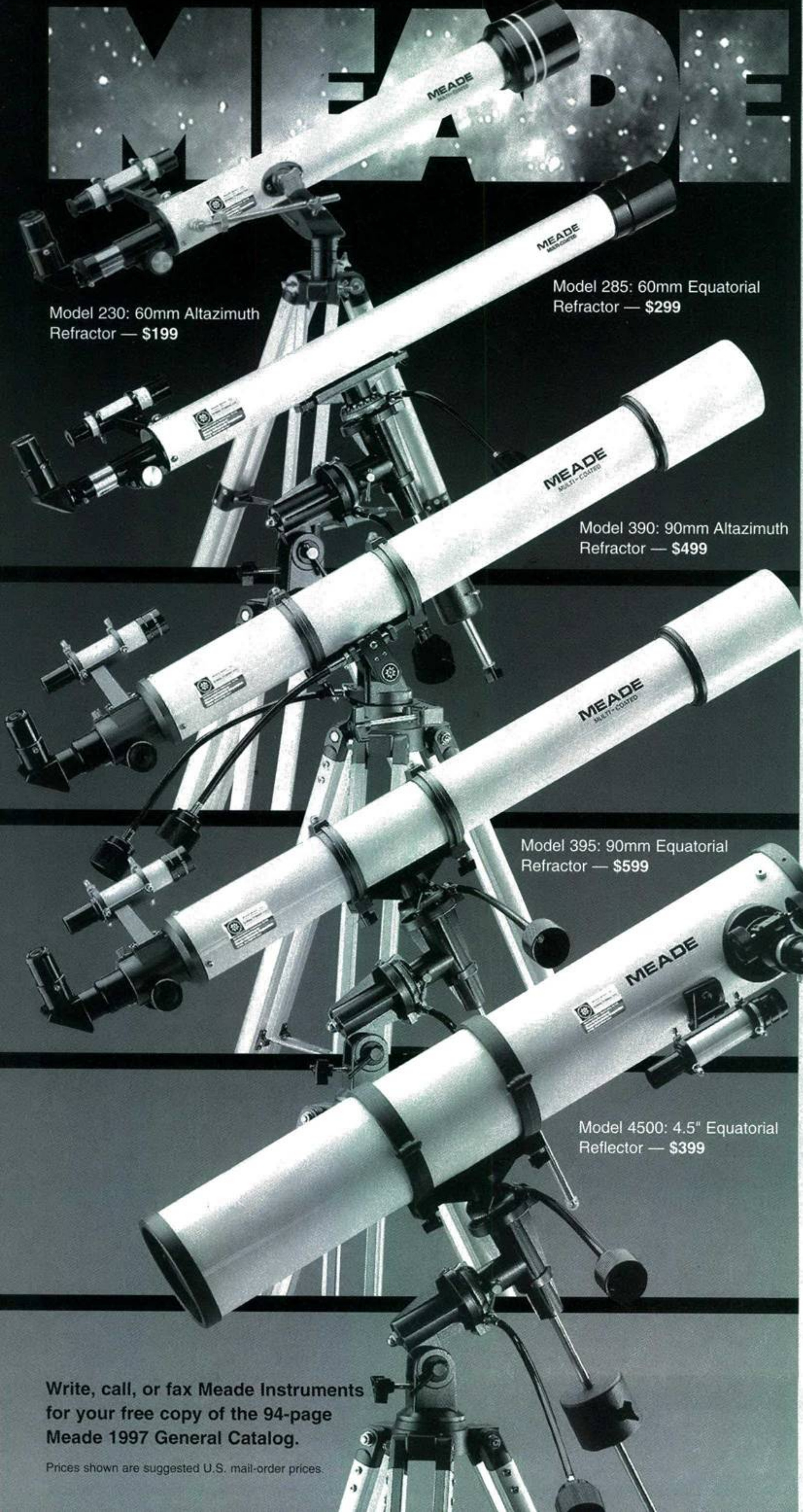

Model 230: 60mm Altazimuth Refractor — **$199**

Model 285: 60mm Equatorial Refractor — **$299**

Model 390: 90mm Altazimuth Refractor — **$499**

Model 395: 90mm Equatorial Refractor — **$599**

Model 4500: 4.5" Equatorial Reflector — **$399**

Write, call, or fax Meade Instruments for your free copy of the 94-page Meade 1997 General Catalog.

Prices shown are suggested U.S. mail-order prices.

Meade® $175 Observer's Package: only *$24.95* with telescope purchase!

Use the **Meade Observer's Package** to enhance the versatility and performance of your Meade telescope. *Priced separately at **$178.80**, the Observer's Package is available at only **$24.95** for a limited time, when purchased with any Meade telescope on this page,* and includes the following important astronomical accessories:

	Meade #126 2x Barlow Lens (1.25"). A high-resolution, multi-coated achromatic Barlow; doubles all eyepiece powers.	**$47.95**
	Meade Modified Achromatic (MA) 12mm Eyepiece. Ideal mid-range magnification for the Moon and planets; multi-coated.	**37.95**
StarNavigator	**Meade Star Navigator™ Sky Software.** Windows-based software that displays over 10,000 galaxies, nebulae, star clusters, and planets on your PC	**79.95**
	Meade Moon Filter. Threads into all Meade 1.25" eyepieces; reduces glare, increases contrast of lunar features.	**12.95**

Total Package Price if purchased separately: **$178.80**

To obtain your Meade Observer's Package:

1. Purchase one of the five Meade telescopes on this page from a Meade dealer of your choosing, between September 1 and December 31, 1997.
2. Send a copy of your dealer's invoice, along with your check for $24.95, or include your VISA or MasterCard number, to Meade Instruments Corp., 16542 Millikan Ave., Irvine, CA 92606.

Requests for the above offer must be received by January 31, 1998. Offer valid only in the U.S.A. and Canada. Please allow 30 days for delivery.

Meade astronomical telescopes and accessories are available from over 500 authorized dealers in the U.S.A. and Canada, including the following authorized Meade Advanced Products Mail-Order Dealers:

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 717-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:
EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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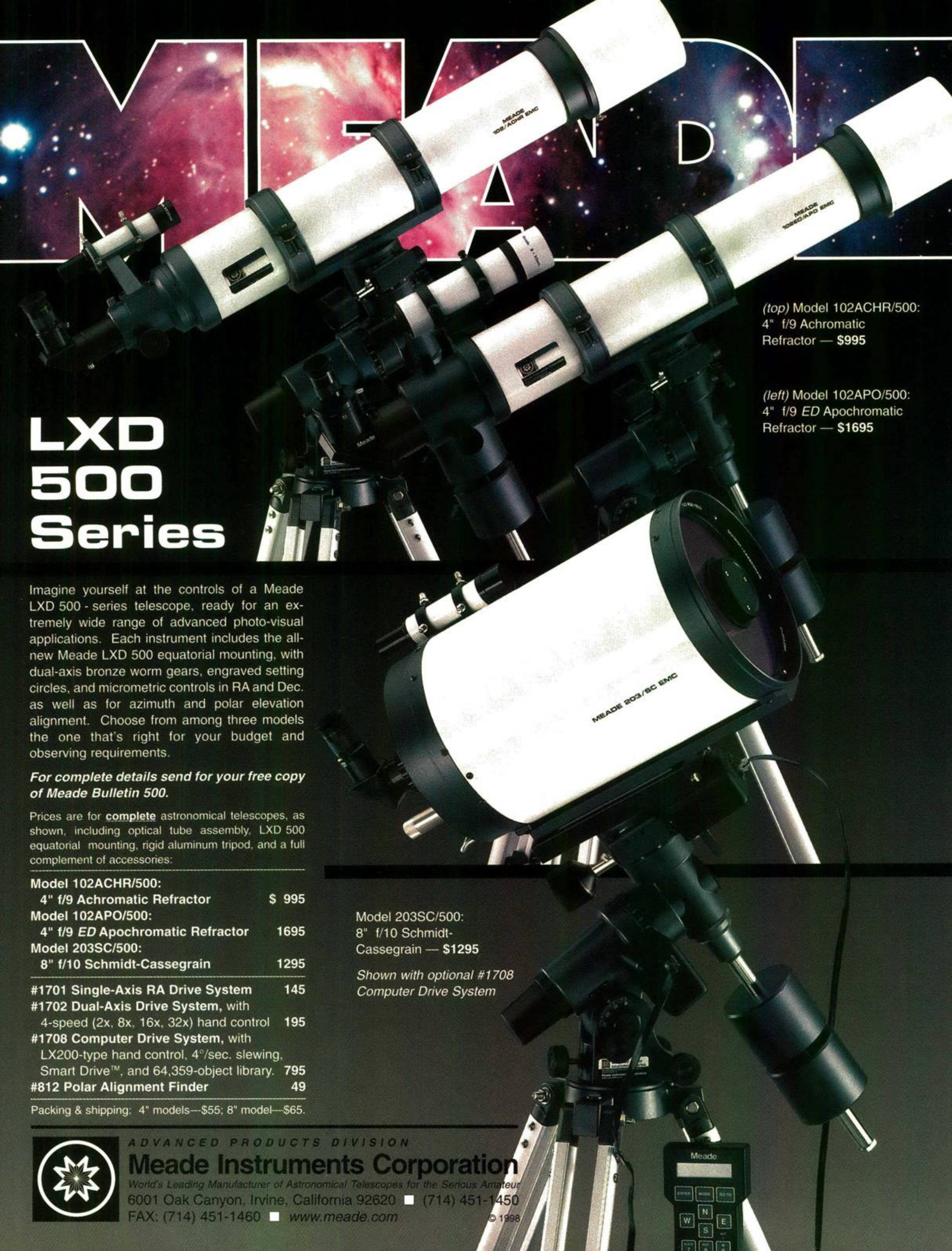

(top) Model 102ACHR/500:
4" f/9 Achromatic
Refractor — **$995**

(left) Model 102APO/500:
4" f/9 *ED* Apochromatic
Refractor — **$1695**

LXD 500 Series

Imagine yourself at the controls of a Meade LXD 500 - series telescope, ready for an extremely wide range of advanced photo-visual applications. Each instrument includes the all-new Meade LXD 500 equatorial mounting, with dual-axis bronze worm gears, engraved setting circles, and micrometric controls in RA and Dec. as well as for azimuth and polar elevation alignment. Choose from among three models the one that's right for your budget and observing requirements.

For complete details send for your free copy of Meade Bulletin 500.

Prices are for **complete** astronomical telescopes, as shown, including optical tube assembly, LXD 500 equatorial mounting, rigid aluminum tripod, and a full complement of accessories:

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A TALKING BACK
FROM OUR READERS

Praise for Planetaria

YOUR ARTICLE IN THE September issue on planetaria ("Reinventing the Planetarium") was outstanding. After reading a short item in *Astronomy* a year ago announcing the closing of the Hayden Planetarium (part of the American Museum of Natural History in New York City), I wrote to its director for details. My letter decrying the tragic closing of the Hayden so impressed the director, noted astrophysicist Neil DeGrasse Tyson, that he called to invite me to the Hayden for a tour.

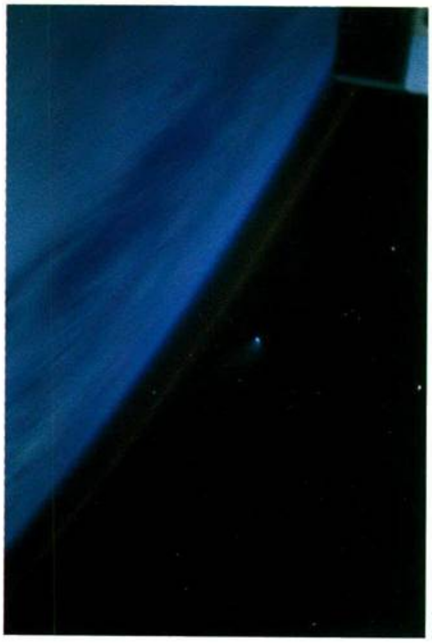
I enjoyed the tour and his discussion. My grandfather introduced me to the wonders of the planetarium shortly after it opened in 1937. It seems Tyson became interested in astronomy and astrophysics as a child in the Bronx when his father took him to the Hayden. He ultimately became its director. I became an avid amateur astronomer and came to work for RCA at Cape Canaveral in the late 50s.

Tyson explained that the new system, which will replace the Zeiss projector, will employ the most advanced optical and digital/electronic equipment available. Fiber-optics projections on the planetarium dome will be done in such minute detail that visitors will be able to use binoculars from their seats in the audience to see the details of nebulae and galaxies. These results are simply impossible with pure optics.

The Hayden closed on January 5, 1997, for a 2½-year reconstruction period. You can be sure I'll be present for the re-opening. I know Dr. Tyson will not let me forget. — *James F. Pinkam, Hudson, New York*

More Shuttle Shots of Hale-Bopp

As a pilot on board the space shuttle Atlantis, I had the opportunity to photograph Comet Hale-Bopp up-close. My photo (right), taken on approximately May 19, 1997, shows the comet in the northwest region of the sky. The shot, photographed with a 50mm lens at f/1.4, was an 8-second exposure taken with ISO 1000 film. Mission STS-84 was the 6th shuttle mission to dock with the Russian space station Mir, pictured in the upper left corner.


NASA

We were very close to a full moon, resulting in the readily visible glow of Earth beneath us. The time from sunset to comet-set was very short, probably less than five minutes, so I was in quite a hurry to snap my photos. Just yesterday I read Don Thomas's account ("Hot Shots," October 1997) of his encounter with Hale-Bopp while on the shuttle Columbia — imagine my surprise. I was so happy to see that you'd printed his stories and photos. I've been a subscriber to *Astronomy* since 1981. Thanks for a great magazine! — *Eileen Collins, Houston, Texas*

Perception of the Crescent Venus

In 1610, Galileo's small telescope revealed Venus as a comparatively large (1') crescent when it was on our side of the sun and closest to us (near inferior conjunction with the sun). Later, when Venus orbited to the opposite side of

(cont. on p. 20)

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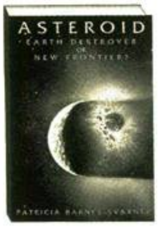

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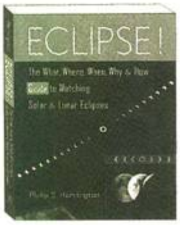

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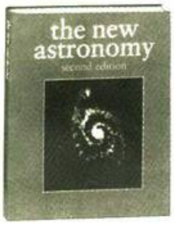

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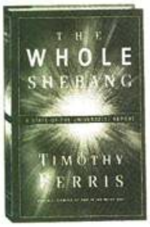

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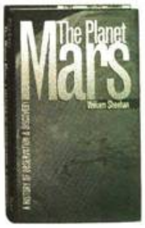

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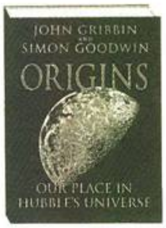

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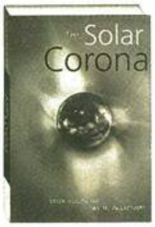

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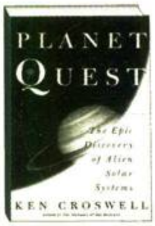

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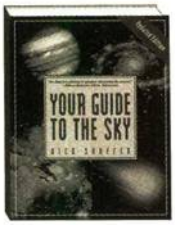

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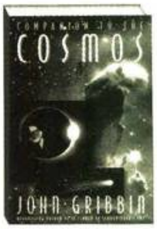

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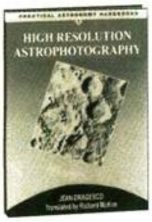

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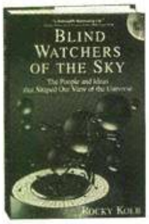

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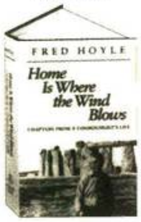

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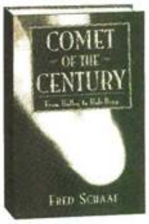

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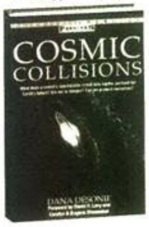

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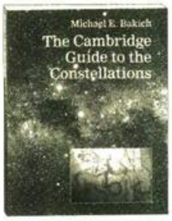

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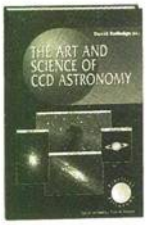

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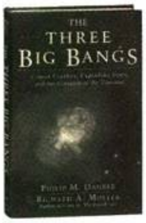

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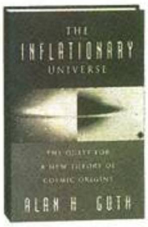

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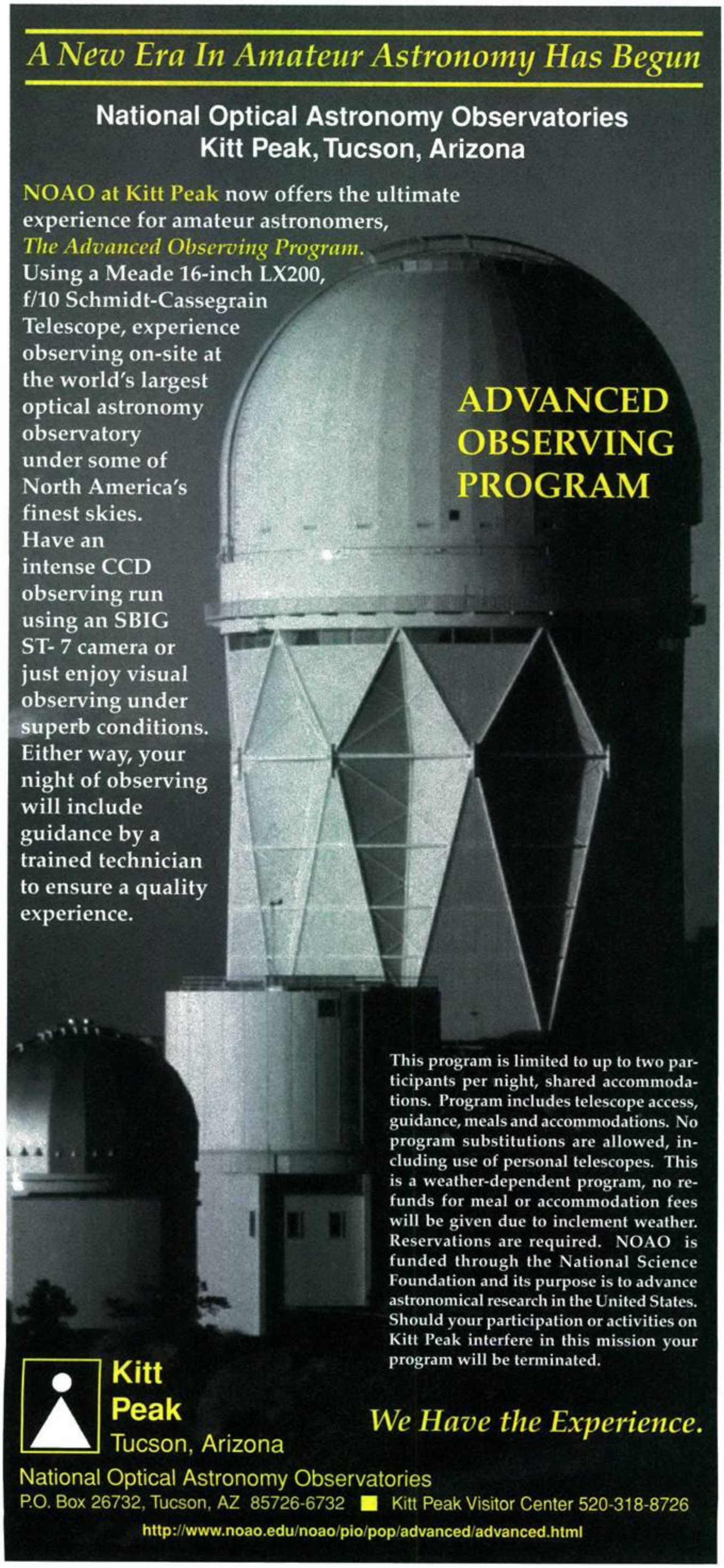

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the sun, it appeared like a dot in his telescope. Was this the first evidence that Copernicus was correct, that the sun and not Earth was the center of the solar system? Maybe, maybe not.

Shortly before and after inferior conjunction with the sun on January 16, 1998, Venus will exhibit its largest crescent in 16 years (62.7"). Unaided eye observers with superior vision should take advantage of this opportunity to try to see it first in the evening twilight before mid-January and once again at dawn after mid-January.

The phenomena of Venus are produced in an eight-year cycle; a study of the perception of its crescent using 100 students was conducted in January 1990. In December 1989, more than 400 southern Indiana high school and university students were given the standard Snellen eye chart test, and the 100 with sharpest vision were selected to take part. Four students with superior vision (20/10) were identified in the testing. The 100 students were briefed individually as to observing times and the position of Venus and were asked to circle the observed shape of Venus on a provided crescent orientation possibility diagram. Because of the "rolling over" of the "cusps" as Venus passes in front of the sun in January, the dates of their observed crescent orientations were critical.

The results of the finalized group of 100 were as follows: About one-third of the students with 20/20 vision perceived the crescent as a dot. The remaining two-thirds said they observed a crescent, but the great mixture of orientations submitted indicated that the acuity of the 20/20 eye fell far short of resolving the 1' crescent. About 15 percent of the observers with 20/15 vision perceived a tiny disk, while a third of the group observed the crescent in the proper orientation. All four of the students with 20/10 vision saw the crescent in its proper orientation for the dates observed.

So Galileo's glimpse of the crescent of Venus doesn't have to have been the first sighting. It could be argued that unaided sightings occurred in pre-Galilean times (by keen-eyed observers) for which there exists no documentation because people feared reprisals from those content with the Ptolemic earth-centered view. — *Gerald D. Ruth, New Albany, Indiana*

New Look Attracts Young Blood

I strongly disagree with Carolyn Strong's complaint in the October issue ("Talking Back") regarding the new look and style of the magazine. As an 11-year-old, I believe that more than simply attracting new customers, this new look is capturing the attention of future scientists (such as myself), and it is greatly helping in our education. — *Steven Gerner, Auckland, New Zealand*

The Quill Quibble Continues

"Anonymous" wrote that the Soviet Union came up with the solution to the problem of needing a pen that would write in zero gravity: Use a pencil ("Talking Back," September 1997). Although I am too young to have been there (born 1958), my training as a reliability and safety engineer tells me that the reason a pencil was not used is that the shavings and graphite posed an unacceptable risk to the astronauts and instrumentation; the cost of the "million-dollar pen" was justified. — *William R. Geimer, Azusa, California*

Astronomy Needs Farmers

The section about the Harvest Moon ("Sky Show," September 1997) indicates a limited number of former farmers on your staff. It notes that longer periods of full moon afforded by the 30-minute difference per day allows farmers to "plow their fields" by moonlight. One plows and sows in spring, but mows and reaps (or harvests) in fall. "Plowing" corn or wheat would make a mighty mess of the crop! I would be willing to wager there aren't too many letters coming in about that one. — *Bob Hillery, Navy Support Facility, Diego Garcia, British Indian Ocean Territory* ◼

Astronomy *invites you to talk back. Send letters to* Astronomy *Talking Back, P.O. Box 1612, Waukesha, WI 53187; e-mail to talking@astronomy.com. Letters may be edited for space or clarity.*

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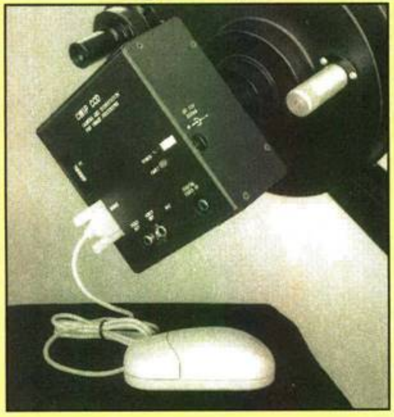

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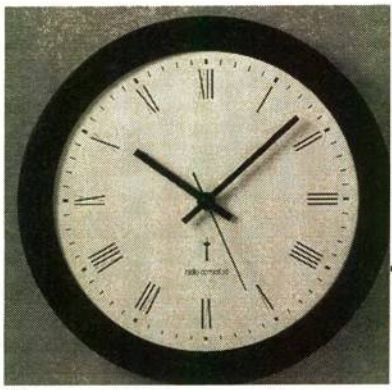

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SPECIAL REPORT

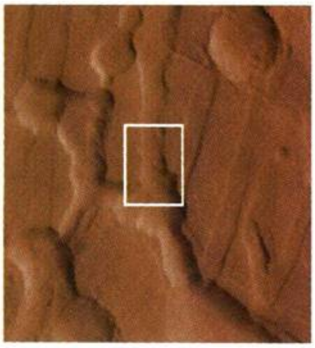
Mars Global Surveyor's First Look at Mars!

NASA probe reaches martian orbit

▶ After a 10-month voyage, Mars Global Surveyor has entered orbit around Mars and thrilled scientists with pictures from its two cameras, a narrow-angle (telephoto) imager, and a wide-angle imager. The first photos, released on October 2, show 50-meter-scale sand dunes filling the floors of craters and a dry riverbed. The pictures give a general impression of a planet with extreme amounts of mobile dust, creating drifts and dunes and blanketing topographic features at tens of meters across.

A second new result was the discovery of the long-sought martian magnetic field, which has a strength only 1/800 of Earth's surface field. Earlier space probes had ruled out a strong active field. The significance of this weak field is still under debate, but if it's a remnant of a once stronger field, that stronger field could have shielded Mars's surface from solar wind and cosmic ray particles, which would have made the early surface more hospitable for life.

Mars Global Surveyor was launched in November 1996, a month before the launch of its more famous sister-ship, Mars Pathfinder. Because of its slower trajectory, Surveyor arrived two months after Pathfinder. It attained Mars orbit on September 11, in a highly elongated orbit, rising to 35,000 miles (56,000 km) on one side of Mars. Repeated dips into the upper atmosphere on the other side will bring the high point downward, until a circular orbit is hopefully attained at an altitude of about 250 miles (400 km). This atmospheric braking maneuver allows the spacecraft to carry more instruments instead of rocket fuel.



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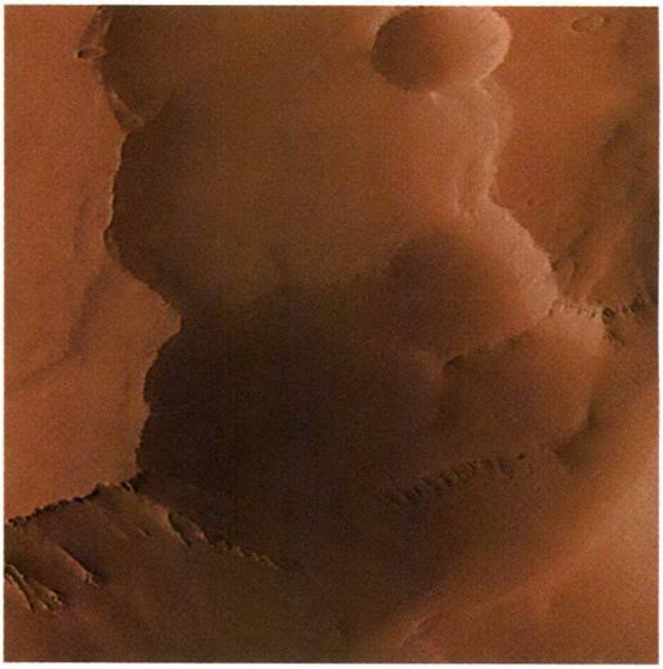
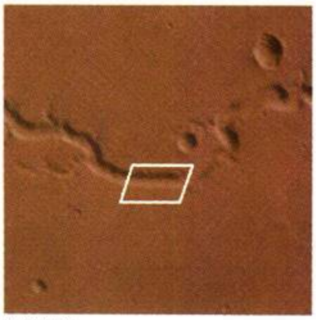


NASA/Malin Space Science Systems

This Mars Global Surveyor oblique close-up (right) of a canyon in the Noctis Labyrinthus valley system shows rough canyon wall structures near the canyon rim. The lower walls appear to be buried under debris. The smallest details are the size of a small office building. The shot was taken during Surveyor's fifth orbit, on September 19. A Viking mosaic, with the Surveyor field inside the white box, is shown above for comparison.



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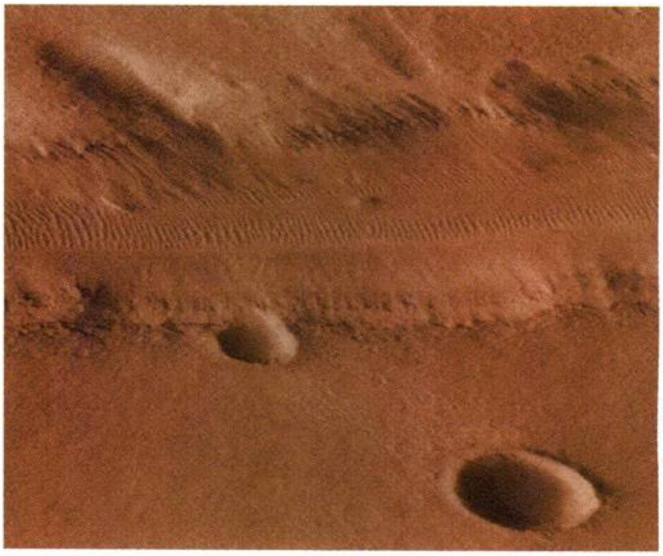

NASA/Malin Space Science Systems

This spectacular Surveyor oblique shot (right) of Nirgal Vallis shows a row of dunes deposited down the middle of the channel floor. Additional dunes and dust drifts suggest that the whole landscape is engulfed in mobile dust. This shot was made during Surveyor's sixth orbit, on September 21. Future Surveyor images will provide even better resolution. A Viking image is shown above for comparison.

The instruments were turned on during the first orbits to allow calibration and to obtain contingency data. Some of the camera's first dozen test shots

(see "Mars" p. 24)

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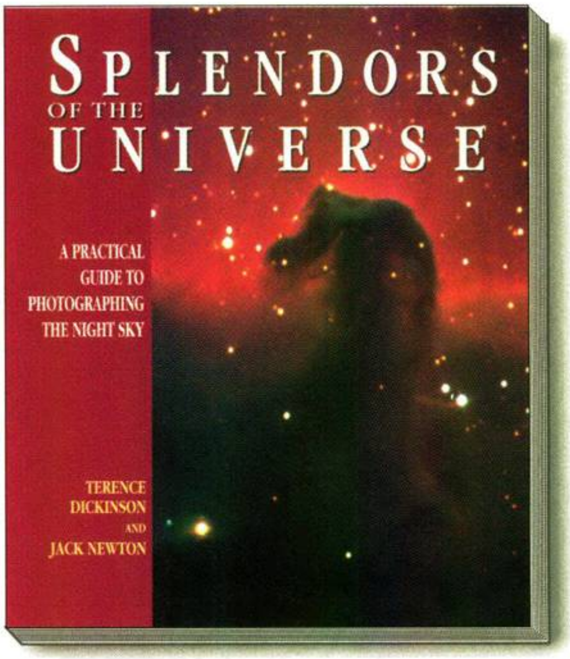
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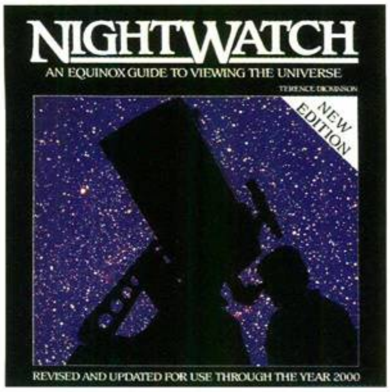
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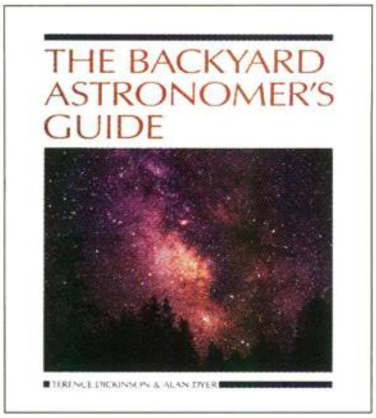
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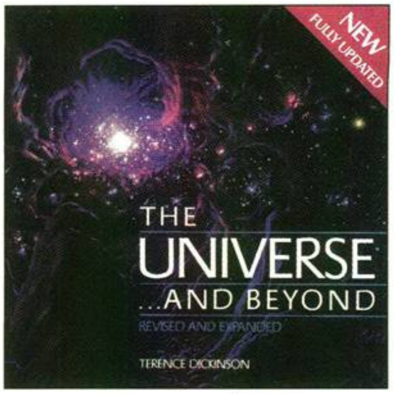
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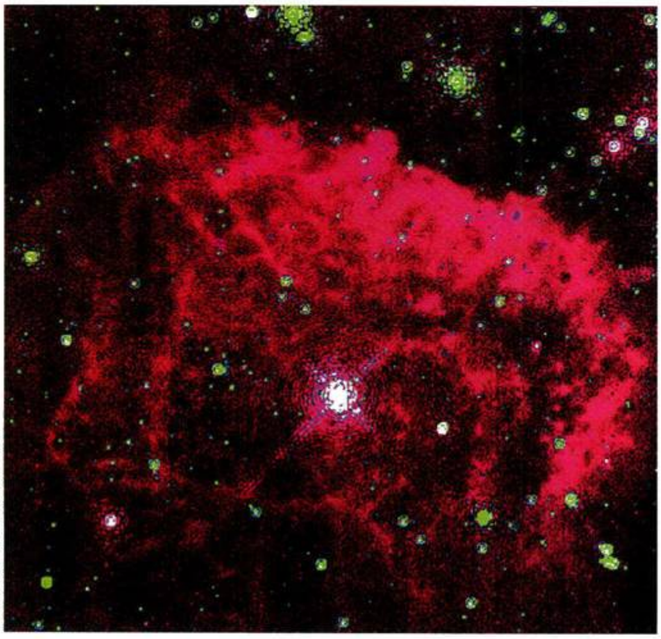

Don F. Figer (UCLA) and NASA

The bright star, known as the Pistol Star, pumps out the energy of 10 million suns. It is surrounded by a nebula four light-years across.

ASTROPHYSICS

Found: One Hot, Bright Star

▶ A new image taken by the Hubble Space Telescope's new NICMOS infrared instrument shows what might be the most luminous of the 200 billion stars in the Milky Way Galaxy. The star, informally dubbed the Pistol Star, is 10 million times more energetic than the sun, meaning it pumps out as much energy in six seconds as the sun does in an entire year!

The Pistol Star has shed a vast cloud of gas and dust, forming the surrounding nebula. The nebula is four light-years across, the distance between the sun and the nearest star. The nebula contains about 10 solar masses and was probably ejected in two massive eruptions about 4,000 and 6,000 years ago.

The Pistol Star probably contains more than 100 solar masses and lies near the stellar upper mass limit. "This star may have been more massive than any other star, and it is without question still among the most massive," says UCLA astronomer Don Figer, who took the Hubble image. The star appears to belong to the Luminous Blue Variable class (see "Angry Giants of the Universe," October 1997), which includes the extraordinarily luminous stars Eta

(see "Hot Star" p. 26)

(Mars)

suffered from exposure problems and clouds. The best images, however, are spectacular, matching or exceeding the sharpest previous pictures, obtained by the Viking orbiters of the 1970s. The resolution in the new images reaches 8 to 12 meters per pixel (picture element). The resolution will be several times better in the final mapping orbit, which will commence in March.

One of the instruments is a spectrometer that measures thermally emitted radiation; it can detect minerals such as carbonates that should have been left behind if Mars once had lakes and seas that evaporated. Surveys by the spectrometer, combined with telephoto shots of truck-sized topography, may soon resolve the mysteries of Mars's ancient climate.

— WILLIAM K. HARTMANN,
PLANETARY SCIENCE INSTITUTE

SOLAR SYSTEM

How to Make Earth's Moon

Impactor larger than originally thought

▶ Ever since the idea was first proposed in 1975, astronomers have agreed that the moon was probably created after a Mars-sized protoplanet smashed into Earth some 4.5 billion years ago at a grazing angle (see "Ask Astro," page 88). The impact blasted crust and mantle material into Earth orbit, where it later coalesced into the moon. But exactly how large was the impactor and how long did the material take to accrete into the moon?

Recent computer simulations by Shigeru Ida of the Tokyo Institute of Technology, and Robin Canup and Glen Stewart of the University of Colorado, provide possible answers. Their results, published in the September 25, 1997, *Nature*, suggest that the impactor must have contained two to three Mars masses to launch enough material into orbit to form the moon. The material coalesced in an orbit only 14,000 miles (22,500 km) above Earth. But 60 to 85 percent of the material ended up in a closer orbit, where it would eventually fall back to Earth. "Once the material in the outer disk accreted to form the moon, its gravitational forces likely scattered the inner disk material back onto Earth," says Canup. "An initial disk mass of two to five lunar masses is required to yield a lunar-sized moon." (Tidal interactions with Earth have slowly nudged the moon outward to its current average distance of 239,000 miles.)

The simulations suggest that the moon formed in a single year, faster than previously thought. Nine of the 27 simulations produced two moons, with one of the moons crashing back to Earth after only 100 years in orbit. "That would have been quite a sight," says Canup.

One nagging problem remains unresolved: Previous simulations done by Al Cameron and colleagues at Harvard University demonstrate than the increased impactor size implied by the new study would produce an Earth-moon system with twice as much angular momentum as they actually have. "Our closest celestial neighbor remains a mystery in many ways," says Canup.

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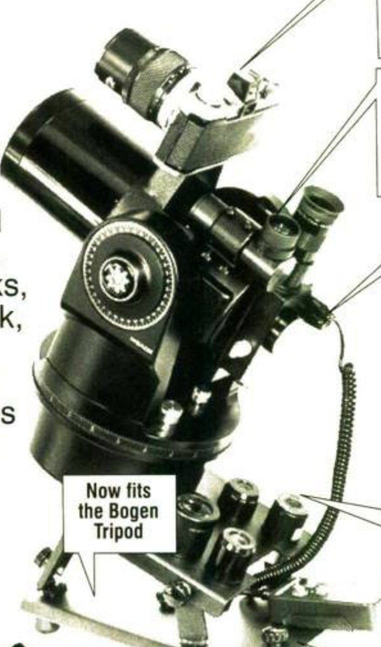
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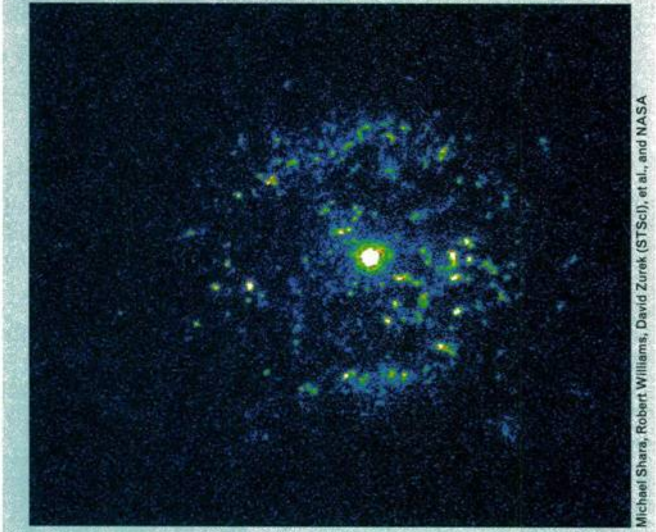
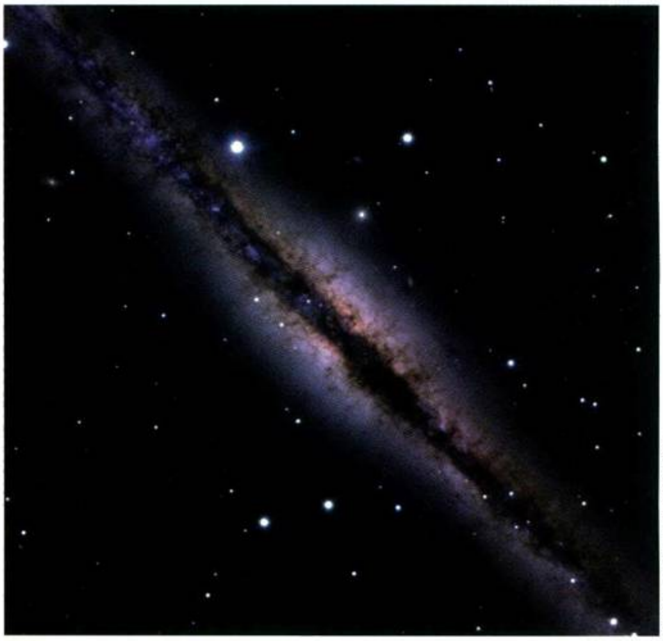
HUBBLE SPACE TELESCOPE



Michael Shara, Robert Williams, David Zurek (STScI), et al., and NASA

HUBBLE SPOTS A BLOBBY NOVA: When the surface of a white dwarf repeatedly erupts in violent explosions called novae, astronomers expect the debris to form smooth shells, each shell representing different explosive events. But Hubble Space Telescope images of a recurrent nova in the dim southern constellation Pyxis shows material concentrated in more than 2,000 solar-system-sized blobs of gas. "Based on these observations, our previous standard view of what nova shells should look like may be fundamentally wrong," says Michael Shara of the Space Telescope Science Institute. The Pyxis nova erupts every 20 years on average. Apparently, fast-moving material ejected from more recent explosions is plowing into slower-moving material ejected in previous explosions, forming the glowing blobs. The nova last erupted in 1966, meaning it is overdue for its next detonation. When it does, Shara and his colleagues are ready to pounce on it with the Space Telescope.



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NGC 891 is a spiral galaxy seen edge-on. Sinewy, dusty clouds extend from the mid-plane of the disk, which is dominated by a dark lane of gas and dust.

DEEP SKY

Polluted Galaxy

Edge-on spiral galaxy launching dust into halo

▶ Have you ever imagined soaring in a spaceship beyond the confines of the Milky Way Galaxy and looking at it from the outside? Unfortunately, our technology isn't quite there yet, but in the meantime we can settle for the image above from the 3.5-meter WIYN Telescope atop Kitt Peak in Arizona. The image of galaxy NGC 891, 30 million light-years away in Andromeda, gives some idea of what our galaxy would look like if we could view it edge-on from the outside.

University of Wisconsin astronomers Christopher Howk and Blair Savage took this image to study how spiral galaxies "pollute" their surrounding halos. The image shows a multitude of sinewy chimney-like clouds of gas and dust extending above and below the plane of the disk into the halo. "What we found was a highly polluted halo," says Savage. "It's a lot cloudier than we expected it to be."

They found that the clouds have been shot out to a distance of 5,000 light-years from the mid-plane of the disk. Astronomers had thought that supernovae propelled the material into the halo. But the complex latticework of clouds suggests that the process is more complicated than that. Howk says, "If the ejection process was just supernova-driven, we might expect to see only a few galactic chimneys." Howk and Savage think the relatively gentle pressure of starlight might be lifting dust into the halo, similar to how the pressure of sunlight produces the yellow-white dust tails of comets.

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COSMOLOGY

Is the Universe Slowing Down?

▶ Will the universe expand forever, or will it eventually slow down to a halt and recollapse into a "big crunch"? It all depends on the density of matter in the universe, because gravity slows the expansion, and also on whether space itself has a repulsive force known as the "cosmological constant" (see "Playing Cosmology's Wild Card," April 1997). Now, with the help of distant supernovae, astronomers are closing in on the answer.

The key to measuring changes in the cosmic expansion rate is finding distance indicators that are visible at distances so great that they represent earlier epochs in cosmic history. Type Ia supernovae — white dwarf stars that undergo thermonuclear explosions — are ideal because they are bright enough to be seen across far reaches of the cosmos and because their peak brightness can be accurately determined from the rate at which a supernova fades.

Now an international team of astronomers has used the Hubble Space Telescope to follow three extremely distant Type Ia supernovae, including the farthest one observed to date (which lies halfway across the universe). By comparing the brightness of these beacons — which indicate their distances — with the rate at which cosmic expansion is carrying them away, the team has determined how much the cosmic expansion rate has changed over time.

"What we found, to our surprise, is that the universe doesn't seem to be slowing down very much, or at all," says Peter Garnavich of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. Garnavich and his collaborators report their results in a paper submitted to *Astrophysical Journal Letters.*

"Our results could mean one of two things," explains Garnavich. "Either there is not much matter in the universe to slow down the expansion, or there's lots of matter but its gravity is countered by a cosmological constant." Their results differ from those obtained by another group of astronomers who observed seven distant supernovae with ground-based telescopes. Early last year, Saul Perlmutter of Lawrence Berkeley National Laboratory in California and his colleagues came up with a much higher slow-down rate, implying a high-density universe. "Using the Space Telescope means we have smaller uncertainties," says Garnavich, but he admits that his group's sample of three supernovae is too small to make conclusive statements about the fate of the universe.

— RAY JAYAWARDHANA

STELLAR EVOLUTION

Merging Stars Explain SN 1987A

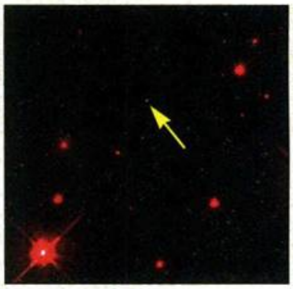
▶ All in all, astronomers were quite pleased with Supernova 1987A because it performed according to expectations, confirming many of their theories of how stars explode. But the supernova exhibited several

Space Station Ready to Go

NASA's $30 billion International Space Station is on schedule. Construction of the first station element, the U.S.-funded, Russian-built Functional Cargo Block, has been completed and is set for a June 1998 launch from the Baikonur Cosmodrome. The first U.S.-built station element is ready to be launched on a space shuttle in July 1998. The first crew is scheduled to arrive in January 1999. The ISS will require 45 launches and, if all goes well, will be completely assembled in early 2003.

Hubble Spots a Lonely Neutron Star

In 1992, the German ROSAT satellite detected a bright x-ray source with no optical counterpart. A Hubble Space Telescope image has revealed the counterpart, a solitary neutron star — a collapsed remnant of an exploded star. Hubble's observations show the star's surface temperature to be 1.2 million degrees F. The neutron star lies in front of a gas cloud known to be 400 light-years away. Despite the neutron star's proximity, it is a dim magnitude 25 in visible light. For an object to be so hot yet so dim, it must be no more than 16.8 miles across.



Fred Walter (SUNY at Stony Brook) and NASA

Hubble has given astronomers their first look in visible light at a solitary neutron star.

Another Asteroid Moon

When the Galileo spacecraft imaged the asteroid Ida in 1993, scientists were delighted to see a one-mile-wide satellite. Astronomers Stefano Mottola and Gerhard Hahn of the German Aerospace Research Establishment have just confirmed a second asteroidal satellite, which orbits the near-Earth asteroid 3671 Dionysus. Mottola and Hahn, working at the European Southern Observatory, detected periodic dips in Dionysus's brightness caused by an orbiting companion. The moon appears to be about 0.3 mile wide, half the size of Dionysus itself.

Is the Sun Getting Brighter?

Using data from three satellites, Richard Willson of Columbia University says the amount of solar radiation reaching Earth increased 0.036 percent between 1986 and 1996, a period of time that covers an entire sunspot cycle. If true, the increase in luminosity would explain some of the warming of Earth's atmosphere. Other scientists, however, point to possible problems with the satellite data and stress that even if Willson's results hold up, an increase in carbon dioxide levels from human activity is still the biggest factor in global warming.

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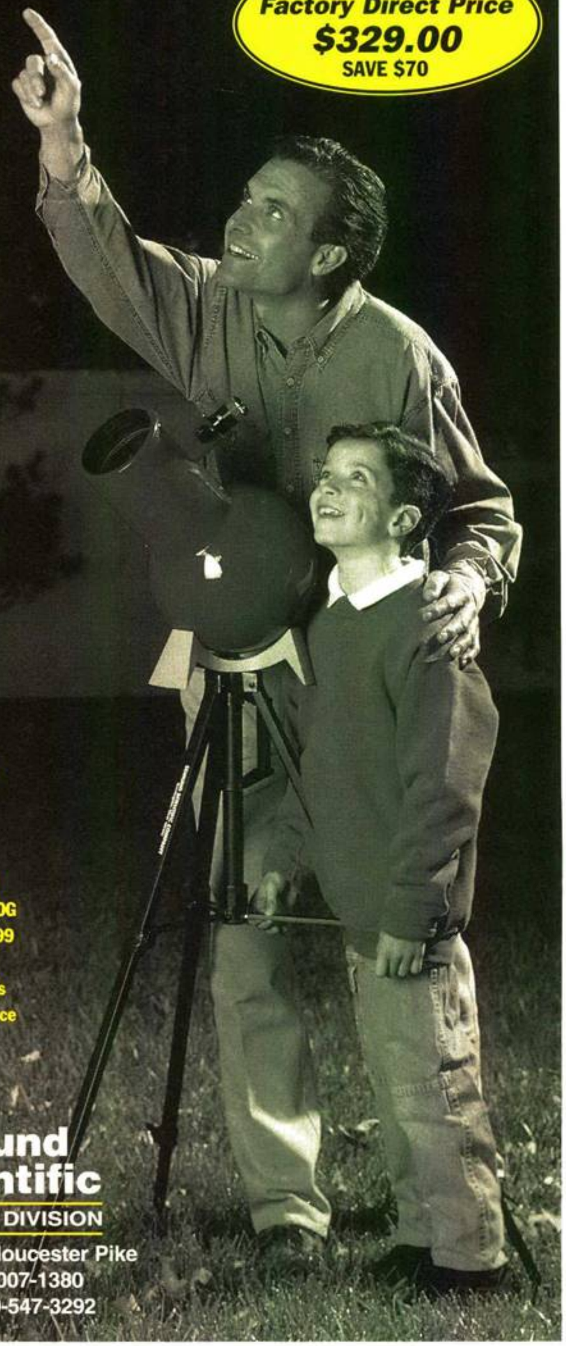

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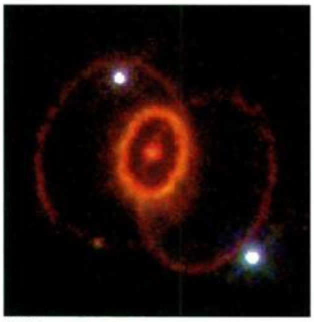
peculiar behaviors that until now have remained unexplained.

Chief among these mysteries is the nature of the progenitor star, Sanduleak –69°202. Pre-supernova photographs show that the star was a blue supergiant, with a diameter of about 50 suns; whereas theory predicts that only red supergiants (with diameters of 1,000 suns) go supernova. Theorists tried to explain this discrepancy by arguing that the progenitor had a low ratio of heavy elements. Unfortunately, recent calculations show this explanation doesn't work.

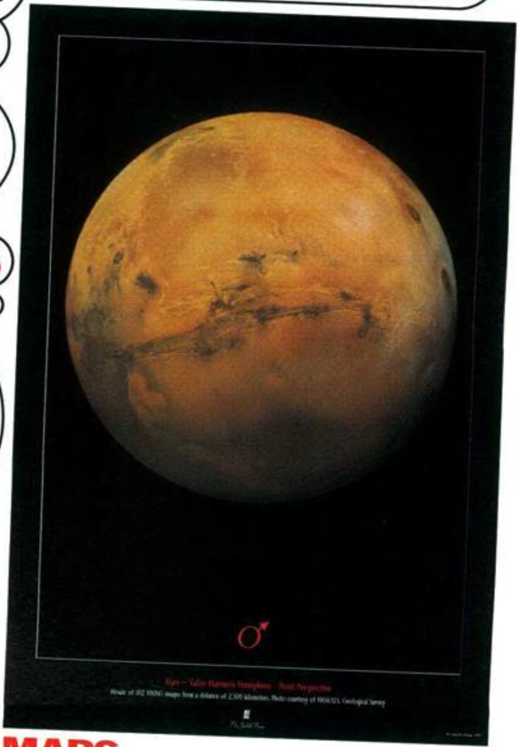

NASA

A stellar merger could explain Supernova 1987A's three ring circus, imaged here by the Hubble Space Telescope.

A second mystery concerns the nature of the nebula and three rings that surround the expanding debris from the explosion. This material was ejected by the star about 30,000 years before it exploded. The nebula is clearly non-spherical, but is otherwise symmetrical about an axis. This configuration strongly suggests that the progenitor was spinning so fast around that axis that it was flattened. Bloated supergiants, however, aren't supposed to be able to spin that fast.

A new theory by Oxford University astrophysicist Philipp Podsiadlowski, which extends earlier research by him and others, kills both birds with one stone. He posits that a companion star spiraled into the progenitor when it expanded into a red supergiant. Tidal forces tore the companion apart, and its material was mixed with the outer layers of the red supergiant. This speeded up the red supergiant's rotation and caused it to shed a tremendous amount of mass along its equator, forming a disk. The mixing of the two stars' outer envelopes also caused the progenitor to shrink into a blue supergiant. The blue star gave off a powerful wind before it exploded, sweeping up the disk material into the inner ring. The two outer rings may represent interacting stellar winds from the two stars before they merged.

Podsiadlowski's model has the added bonus of explaining some of the peculiar chemical anomalies in the explosion debris. "There is no other model at the moment that can even start explaining these unusual features," says Podsiadlowski. "It will be very difficult to construct an alternative model, and if there will be, it will almost certainly be much more complicated or just a variation of the basic merger model." A



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25
YEARS

Essay Competition

Select from one of three possible topics and write a 1,000-word essay. The due date is March 15, 1998. The best entry in each category will appear in the August 1998 issue of *Astronomy* and receive a publication fee of $500. The judges will be the editors of *Astronomy* magazine. Be sure to include your name and address, and label the essay with the question you have selected. Your submission must be typed, double spaced, and sent by U.S. mail (to 21027 Crossroads Circle, Waukesha, WI 53187) or e-mail to: essay@astronomy.com.

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International Photo Competition

Send your CCD images (Divison 1) and slides and prints (Divison 2) of great sky shots taken between May 1, 1997, and March 1, 1998. We will accept entries in three categories — Solar System, Deep Space, or Unique Events until April 1, 1998. Mark entries "Photo Contest" (as opposed to Hot Shots). Label entries with category and division, name and address, and technical information. The top entry in each category will win $100. All winning entries will appear in the August 1998 issue of *Astronomy* after judging by the magazine's editors and designers. Send entries via U.S. mail (to 21027 Crossroads Circle, Waukesha, WI 53187) or e-mail to: photos@astronomy.com.

Children's Corner

We invite submissions in three categories: drawings and paintings, astronomy essays, and photos from young astronomers. We invite astronomers to enter in two age groups: five through 11 and 12 through 16. Essays must be 500 words or fewer and must be typed. Be sure to indicate category, age group, name, and address. We will award $50 to the top winner *in each category in* each age group. Winning entries will appear in the August 1998 issue and will be judged by the magazine's editors and designers. Send entries via U.S. mail (to 21027 Crossroads Circle, Waukesha, WI 53187) or e-mail to: kids@astronomy.com.

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Save money and have fun! Paul Amneus built a telescope with his Smithy and saved $2300!

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Above: The Smithy CB-1220 XL

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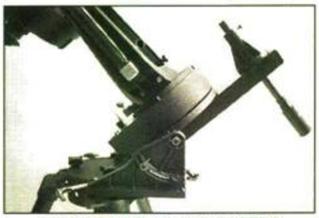

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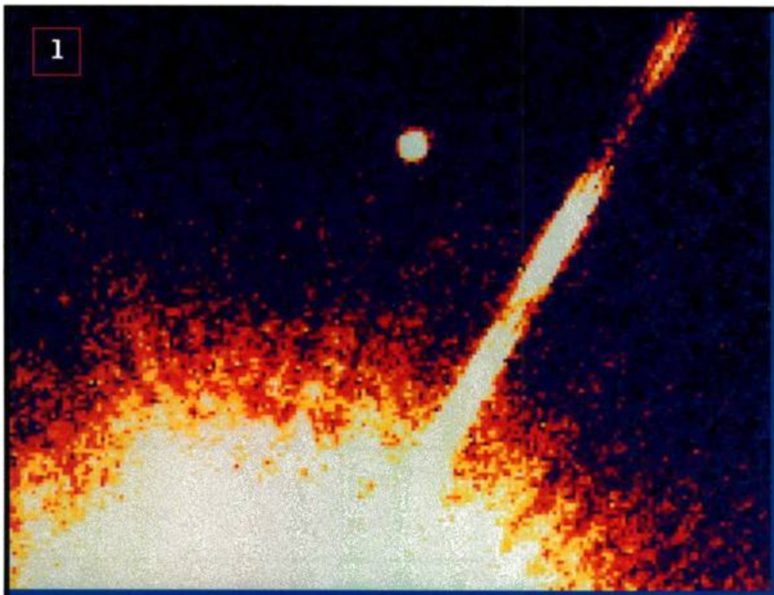
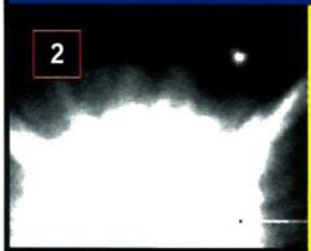
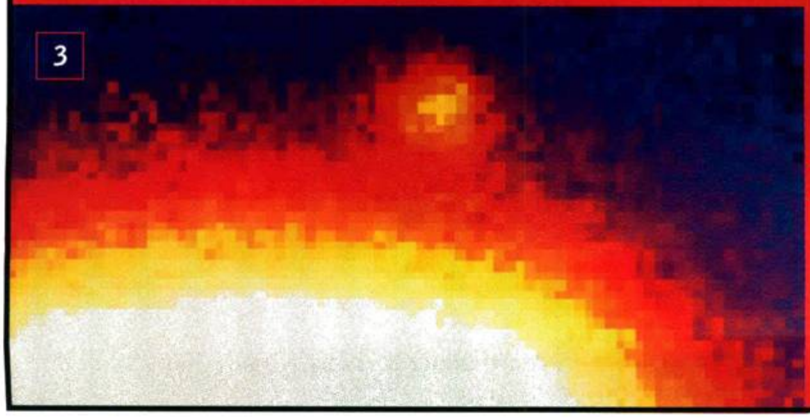
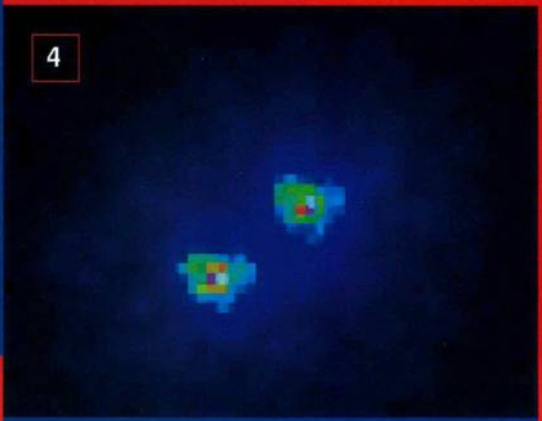


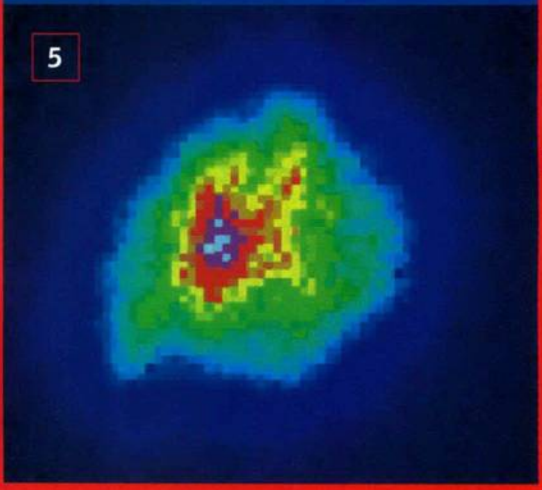


The small dot in each of these images is a brown dwarf orbiting the star Gliese 229B, about 19 light-years from Earth. Below, we see a ground-based image taken without the benefit of adaptive optics (3). Above, we see a Hubble Space Telescope image (1). A ground-based image using adaptive optics (2) appears on the left.

Top: Shrinivas Kulkarni (Caltech), et al., and NASA. Center: Michael Lloyd-Hart (University of Arizona/Steward Observatory), et al. Bottom: Tadashi Nakajima (Caltech), et al.





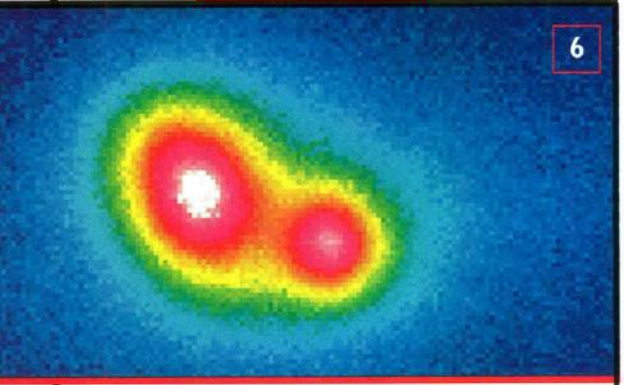


Ground-based telescopes equipped with adaptive optics can resolve the two members of a binary star system (top, 4); stars that appear smeared together when adaptive optics are not used (above, 5). European Southern Observatory

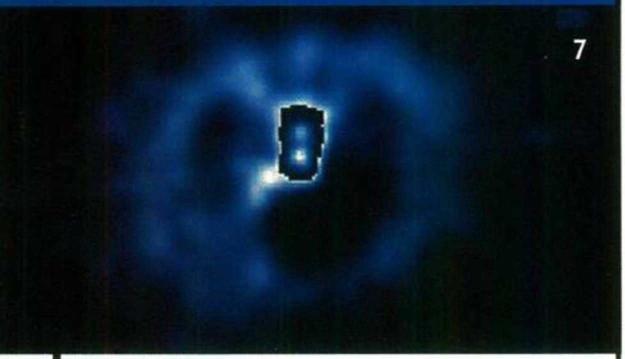
Stars

The new technology of adaptive optics will revolutionize astronomy, revealing amazing new things about the universe.

by Glenn Gombert and Marsha Wolf



Using adaptive optics, the 3.6-meter Canada-France-Hawaii Telescope imaged a double nucleus in the galaxy Markarian 273 (6). The two nuclei are only 1 arcsecond apart. At the galaxy's distance of 500 million light-years, this translates to a physical separation of 2,200 light-years. The double nucleus probably arose from a galactic merger. Johan H. Knapen (University of Hertfordshire), et al.



University of Hawaii astronomers used an adaptive optics-equipped telescope to resolve a disk of gas and dust orbiting the young binary star GG Tau, about 460 light-years away (7). Tidal interactions with the binary star are clearing out the inner part of the disk.

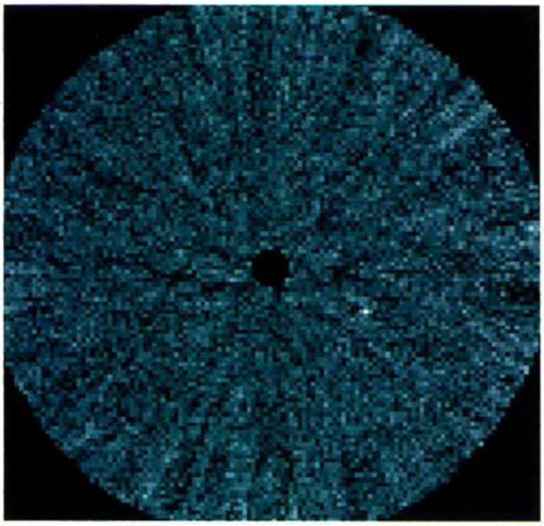
Claude Roddier (University of Hawaii)

THE LAUNCH OF THE HUBBLE SPACE Telescope seven years ago began an era of discovery that is revolutionizing our view of the universe. It seems that everywhere Hubble looks, it finds new and surprising things which answer some questions about the universe's current state and evolution, but which also generate new questions and force astronomers to re-examine many of their most cherished theories.

This revolution of how we view the universe has resulted from our ability to lift a large optical telescope above the blurring effects of Earth's atmosphere. Although much larger ground-based telescopes view the sky from high-altitude observing sites around the world, their image clarity simply cannot match that of an orbiting telescope such as Hubble.

Accompanying the new views granted by Hubble is a quiet, but equally exciting, revolution underway in ground-based astronomy. It is based on the recently declassified technology of adaptive optics, which originated in the mid-1980s during the U.S. military's Strategic Defense Initiative, better known as the "Star Wars" program. Over the last several years, eight adaptive optics systems have become operational at observatories all over the world, and at least 20 are being developed.

Adaptive optics use lasers, sensors, computers, and deformable mirrors to compensate for atmospheric blurring, the plague of all ground-based observations. Imagine an instrument that could capture the image clarity of a space telescope and the sheer brute light-gathering power of a large ground-based telescope. In principle, adaptive optics systems on large telescopes could provide higher resolution pictures of the universe than Hubble, allowing us to look deeper and farther than ever before. Adaptive optics will image planets orbiting other suns and answer questions about the origin and fate of the universe. "Adaptive optics is a technology whose time has come," says Robert Fugate of the U.S. Air Force, one of the technology's pioneers. "It could have as much impact on ground-based optical astronomy in the 21st century as did the invention of the telescope in the 17th century."



Large telescopes equipped with adaptive optics should soon be able to directly image planets orbiting nearby stars. The white blip is a simulation of how a Jupiter-like planet would appear orbiting a star 24 light-years away.

David Sandler (ThermoTrex Corp.) and Steward Observatory

To Explore Strange New Worlds

Astronomers are eager to use adaptive optics for a wide range of studies, but the detection of extrasolar planets appears near the top of the priority list. Over the past few years, astronomers have detected about ten extrasolar planets through small variations in their host stars' spectra. Astronomers are observing the "wobble" of the star induced by the gravity of an orbiting planet. The wobble's period and magnitude allow astronomers to calculate the planet's orbit and minimum mass. But this method generally takes years of observations to find planets and it yields no further information about them.

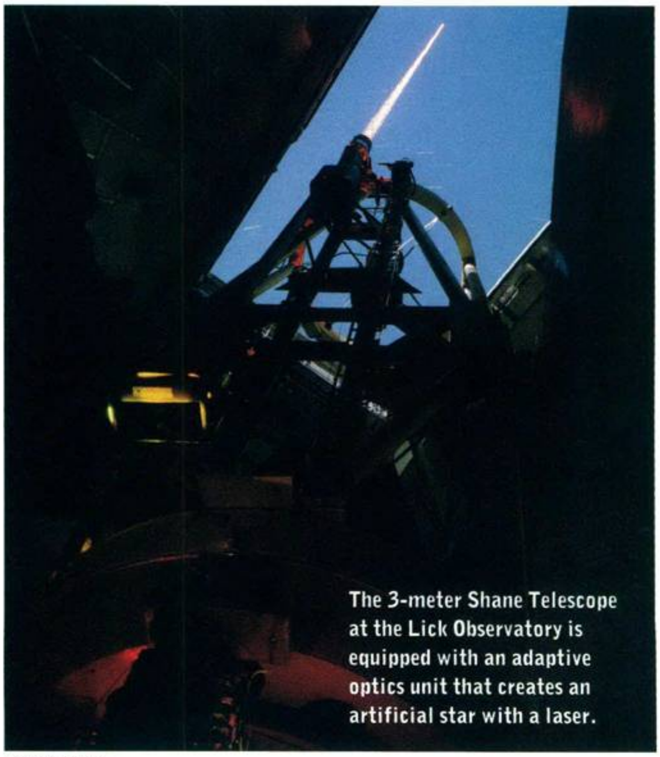
Adaptive optics should enable astronomers to move from indirect to direct detection by actually

How Adaptive Optics Work

The atmospheric "seeing" problem is familiar to backyard observers, who spend many long minutes staring into a telescope, waiting for that brief instant of clarity when Jupiter's bands or Great Red Spot, or the Cassini division in Saturn's rings, jump out in perfect clarity. These instants occur when the atmospheric cone within the telescope's field of view is fairly uniform.

Blurring is normally caused by turbulent air cells moving through the telescope's field. A small telescope typically samples a portion of atmosphere nearly equal to the size of these atmospheric cells, allowing one to completely fill the aperture from time to time. However, if multiple cells occupy different portions of the telescope's aperture, each cell distorts the light from the astronomical object in a different way — blurring and smearing the image. Hubble overcomes these effects due to its location above Earth's atmosphere.

Large telescopes, particularly professional scopes in the 6- to 10-meter class, suffer more than small ones due to the fact that their apertures are larger than an atmospheric cell. As a result, the telescope never gets a completely clear picture. Enter adaptive optics, which can sample and correct distortions imparted by the atmosphere. The effect: performance nearly equivalent to a large telescope above the atmosphere.



The 3-meter Shane Telescope at the Lick Observatory is equipped with an adaptive optics unit that creates an artificial star with a laser.

Lick Observatory

Adaptive optics systems perform two different tasks to compensate for rapid fluctuations in the atmosphere. First, these systems measure the distortions seen by the telescope on an instant-by-instant basis. Second, they correct for these fluctuations in real time, before the atmosphere changes the distortions significantly (typically a few hundredths of a second).

To sense atmospheric fluctuations, Robert Fugate's Starfire Optical Range system uses a laser that creates an "artificial star" in the atmosphere. The laser is tuned to a wavelength of light that is absorbed and re-emitted by a layer of sodium atoms about 55 miles high. Starfire's 1.5-meter telescope picks up the light from this "star" and uses it to precisely measure the momentary variations in the atmosphere. A device called a wavefront sensor examines the artificial star's image and provides information for the precise corrections that are required to compensate for distortions. A high-speed computer monitors these instantaneous variations and computes the corrections that must be applied on a continual basis to "freeze" the turbulence. The computer sends instructions to a series of actuators, which push and pull on a deformable secondary mirror in just the right way to compensate for atmospheric turbulence.

Adaptive optics systems at other observatories use similar methods, although many observe real stars close to the object of interest rather than using a laser to create an artificial star.

imaging planets next to their parent stars, which should greatly accelerate the pace of discovery. In addition, adaptive optics will improve on some of the current indirect detection techniques, allowing them to detect lower-mass planets.

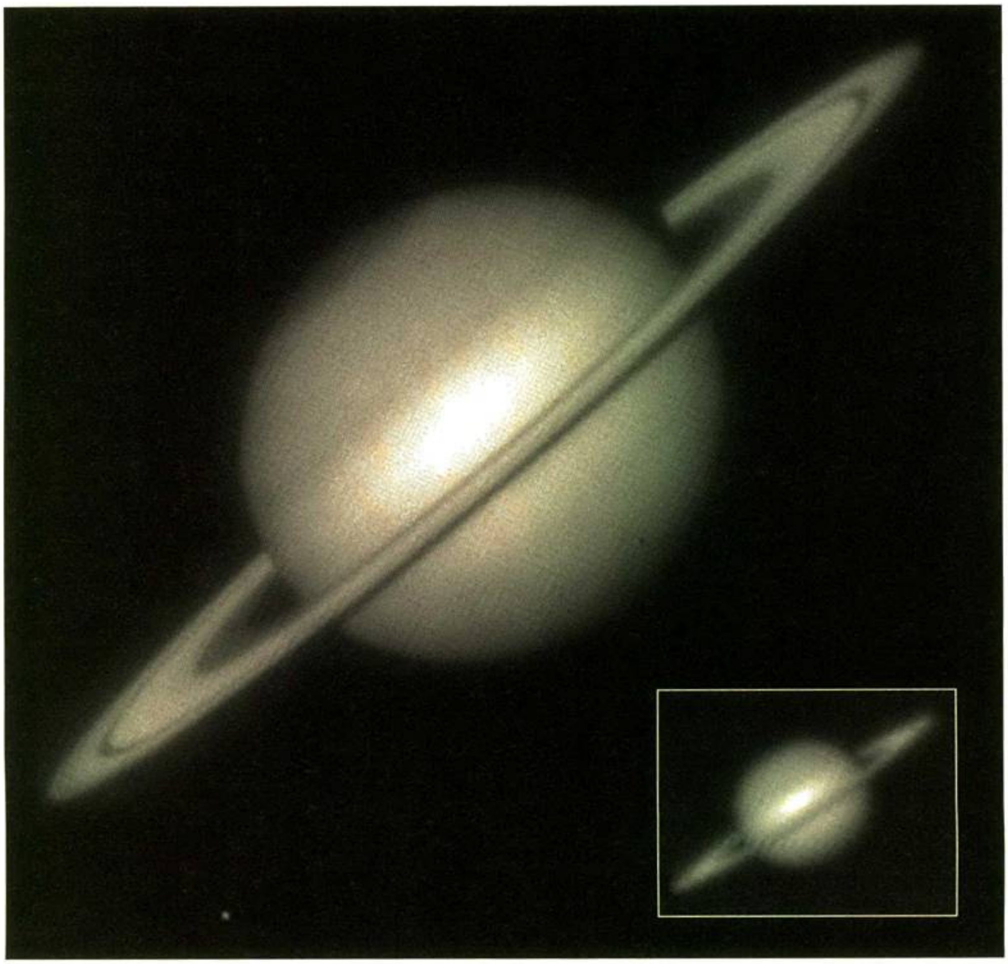
The Lawrence Livermore National Laboratory in California is putting together an extrasolar planet detection system using adaptive optics that will be connected to the giant 10-meter Keck II Telescope in Hawaii. The team's goal is to develop a system capable of discriminating the image of a planet from that of a star that is 10 to 50 billion times brighter and separated by only 4 arcseconds (the width of a penny as seen at seven miles). Although considerable problems remain to be worked out, astronomers expect the Keck II system — in a few hours of observing time — to be able to image giant planets in distant orbits around nearby solar-type stars such as Epsilon Eridani and Tau Ceti.

A Poor Man's Spacecraft

Adaptive optics won't be limited to the study of planets orbiting other stars. The resolution achieved with adaptive optics systems will give ground-based telescopes the ability to view weather patterns on other planets in our solar system. It will also allow astronomers to map features on near-Earth asteroids, which will tell them about the asteroids' histories and chemical compositions. This capability should greatly enhance solar system studies that could be done previously only by space probes — which are far more expensive and subject to breakdown. It will also partially relieve tight constraints on precious Hubble Space Telescope observing time.

A group of astronomers at the European Southern Observatory in Chile, using a 3.6-meter telescope, has managed to accomplish something the twin Voyager spacecraft were unable to do: image surface features on Saturn's large moon Titan. Without adaptive optics, the telescope never could have resolved these markings. The team observed Titan at infrared wavelengths that can penetrate the moon's thick atmospheric shroud. The Voyager spacecraft, which flew right by the moon in 1980 and 1981, were not equipped with an infrared imager.

NASA's Goddard Space Flight Center and the Air Force's Starfire Optical Range in New Mexico are collaborating on a solar system project. The team, led by Fugate, has been taking high-resolution images of Saturn and Titan, but their primary interest has been asteroids. Using the relatively modest 1.5-meter telescope at the Starfire Range, Fugate's team has shot a "movie" of the oblong asteroid Vesta as it tumbles through space. The team has also determined that Ceres — the largest asteroid in the solar system — is not perfectly spherical. Future work with larger telescopes will enable astronomers to study the sizes, shapes, and rotation rates of smaller asteroids.



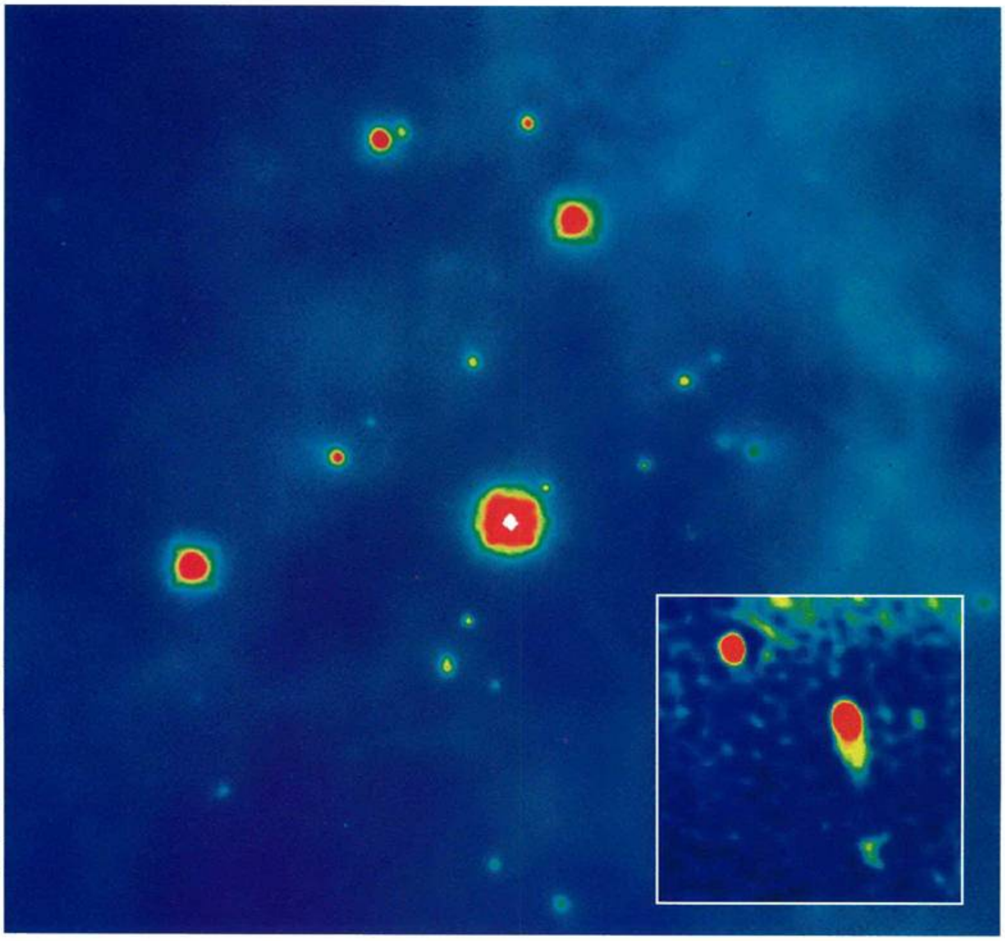
Robert Fugate, et al. (Starfire Optical Range, USAF Phillips Laboratory)

By compensating for atmospheric blurring, adaptive optics can make an enormous difference. The large image of Saturn was taken with adaptive optics; the inset image was taken without adaptive optics. Both come from the 1.5-meter telescope at the U.S. Air Force's Starfire Optical Range in New Mexico.

The Mt. Wilson Observatory in California is also investigating what adaptive optics can do for ground-based solar system astronomy. The 100-inch (2.5-meter) Hooker Telescope has been outfitted with an adaptive optics system called ADOPTICS, which can achieve a resolution of 0.06 arcsecond (comparable to Hubble's resolution). The system's 1996 images of Vesta show surface details a mere 40 miles across, a resolution unobtainable by a ground-based telescope without compensating for the atmosphere. This system has the potential to engage in long-term projects such as monitoring volcanic eruptions on Jupiter's large moon Io.

Quasar Fuzz

Much farther from home, adaptive optics are playing an active role in the study of quasars, which are among the most luminous objects in the universe. Astronomers believe quasars are highly energetic galactic cores that are powered by supermassive black holes. Because some quasars are extremely far away, the light we see from them was generated when the universe was much younger. By studying these objects, astronomers will learn how quasars and their host galaxies have changed over a huge stretch of cosmic history.



Robert Fugate, et al. (Starfire Optical Range, USAF Phillips Laboratory)

With adaptive optics, modest-size telescopes such as the 1.5-meter reflector at the Starfire Optical Range can resolve exquisite detail. The large image shows the four Trapezium stars in the Orion Nebula. The inset shows a detail from the large image.

Studies of quasar host galaxies should provide information about their relationship to the black-hole-driven central engines. Some quasars are radio-loud, meaning they emit very strongly at radio wavelengths. But most quasars are radio-quiet. Previous optical observations have generally found that radio-loud quasars are found inside more luminous, larger, elliptical galaxies, and that radio-quiet quasars exist in spiral galaxies. However, this conclusion is not definitive; there are in fact recent claims of some radio-quiet quasars existing in elliptical galaxies.

This conflict could be a result of the difficulty of the observations. Astronomers have a hard time imaging a dim galaxy around a blazingly bright quasar. The light from the quasar dominates the brightness of the galaxy near the nucleus, leading to potential misinterpretations of the structure of the surrounding galaxy.

It's much easier to separate the quasar from its host galaxy in the infrared part of the spectrum, which reduces the quasar's brightness relative to the galaxy. The infrared is also the range of the spectrum in which most adaptive optics systems operate. One example is the University of Arizona's FASTTRAC II, which is attached to the Multiple Mirror Telescope. This system is about to be upgraded to a more sophisticated system which will have a theoretical resolution of 0.04 arcsecond, exceeding that of the Hubble Space Telescope in infrared light.

Eric Hooper of the Harvard-Smithsonian Center for Astrophysics is conducting an ongoing program to observe quasar host galaxies with the University of Arizona adaptive optics system. Hooper's observations will complement Hubble Space Telescope images of the same quasar fields in visible wavelengths. The combination of Hubble and adaptive optics images will reveal the nature of quasar host galaxies, and how they relate to the highly-energetic cores.

Young Galaxies

The Hubble Deep Field — released in January 1996 — contained a number of galaxies that seem to be the most distant objects observed to date. Subsequent ground-based observations have confirmed that these galaxies date to an epoch reaching back to the time when the universe was only five percent of its current age, only a few hundred million years after the Big Bang. This means these galaxies may be undergoing the first burst of star formation associated with the initial collapse of gas clouds into galaxies.

These Hubble observations have further fueled astronomers' ongoing desire to look deeper into the early evolution of the universe. Hubble images seem to suggest that elliptical galaxies developed quickly into their present shapes, while spiral galaxies evolved into their present shapes over a longer period. These observations challenge recent observations that indicate a rapidly expanding universe because such a universe shouldn't be old enough for galaxies to have evolved into the mature forms seen by Hubble.

The need to look at the structure of these early galaxies becomes essential in these studies. Up until now, ground-based telescopes could provide spectra, but only Hubble could image details in the galaxies' shapes and configurations. With the advent of adaptive optics, however, the world's largest telescopes, with their larger mirrors, should be able to provide higher resolution images than Hubble, to afford a view of the young pristine universe in its early stages of evolution.

Black Holes and Gravitational Lenses

The study of our own galaxy can also be aided by the use of adaptive optics. Our galactic center is buried deep in a shroud of obscuring dust. Images taken in visible light cannot see through the dust, but infrared light penetrates right through it. The University of Arizona's FASTTRAC adaptive optics system, used on both the university's 60- and 90-inch telescopes, provided a high-resolution infrared image of the galactic center, one of the first direct images of the prodigious radio source at the center of our galaxy, believed to be a million-solar-mass black hole.

Astronomers think that nearly all large galaxies harbor massive black holes in their cores. This conclusion is based primarily on recent Hubble observations. Astronomers have developed a technique of using the Space Telescope to observe the motions of stars orbiting the centers of galaxies. Superfast stellar motions belie the presence of a massive object. This technique has been tried on ground-based telescopes, but they have proven to be inadequate due to atmospheric blurring.

Now that a viable technique has been demonstrated, ground-based telescopes equipped with adaptive optics can come to the aid of overworked Hubble once again. Surveys of many galaxies should support or disprove the conclusion that nearly all large galaxies have sizable black holes at their centers.

Adaptive optics will also help astronomers find gravitational lenses, which occur when the gravity from a very massive object, such as a black hole or galaxy, bends the light rays from an object behind it and projects multiple images of the distant object around the massive object. Since the first gravitational lens was discovered in 1979, very few lenses have been observed, and bright quadruple lenses are extremely rare.

But the increased resolution gained from adaptive optics means that searches can be extended to fainter, farther objects. Astronomers can use quadruple lenses to measure the distances to faraway galaxies and quasars. With accurate distance measurements, astronomers will be able to determine how fast the universe is expanding, which in turn will help answer the question of whether the universe is open and will expand forever, or whether it is closed and will eventually begin to collapse upon itself.

The Future

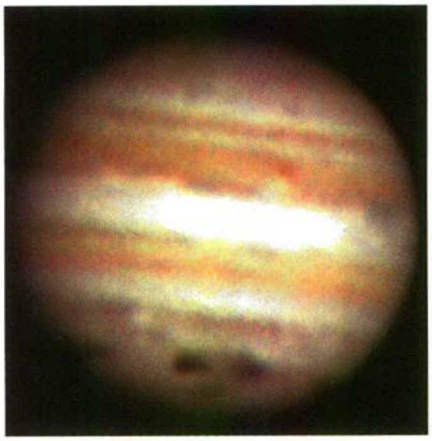
The projects listed above are just a sampling of what adaptive optics can accomplish. Using an adaptive optics unit paired with the 3.6-meter Canada-France-Hawaii Telescope, astronomers have clearly resolved a double nucleus in a galaxy 500 million light-years away. The nuclei are separated by a mere 1 arcsecond. Astronomers believe the double nucleus represents the cores of two merging galaxies. University of Hawaii astronomers have imaged a dusty disk around a newborn binary star. The two young stars appear to have cleared out the inner part of the disk, resulting in a circumbinary disk.

Even amateur astronomers are getting into the game. Stellar Products, of San Diego, California, manufactures a relatively low-cost and easy-to-use adaptive optics system, the AO-2, that is specifically designed to work with just about any type of backyard telescope. The company is also developing a more advanced version called the AO-5. Santa Barbara Instruments Group (SBIG) is just about to come out with a low-cost adaptive optics unit for their ST-7/8 line of CCD cameras.

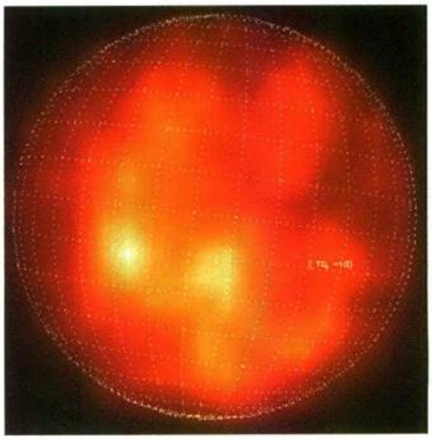
What began as a classified military project, adaptive optics has seen an explosive growth in its use at professional astronomical observatories all over the world since its declassification in 1991. When all the currently planned adaptive optics systems become operational, ground-based astronomy will never be the same. ■

Glenn Gombert (gleng@infinet.com) is a member of the Miami Valley Astronomical Society in Ohio and an avid CCD imager. He co-authored "The Year of the Comet" in the January 1997 issue of Astronomy. *Marsha Wolf (marsha.wolf@worldnet.att.net) is an electro-optical engineer for Anteon Corporation at Wright-Patterson Air Force Base in Dayton, Ohio, where she works with high-power lasers for materials evaluation and processing.*

Even amateur astronomers can enjoy the benefits of adaptive optics. This image of Jupiter was taken with a 10-inch telescope equipped with an adaptive optics system made by Stellar Products.



Donald Bruns (Stellar Products)

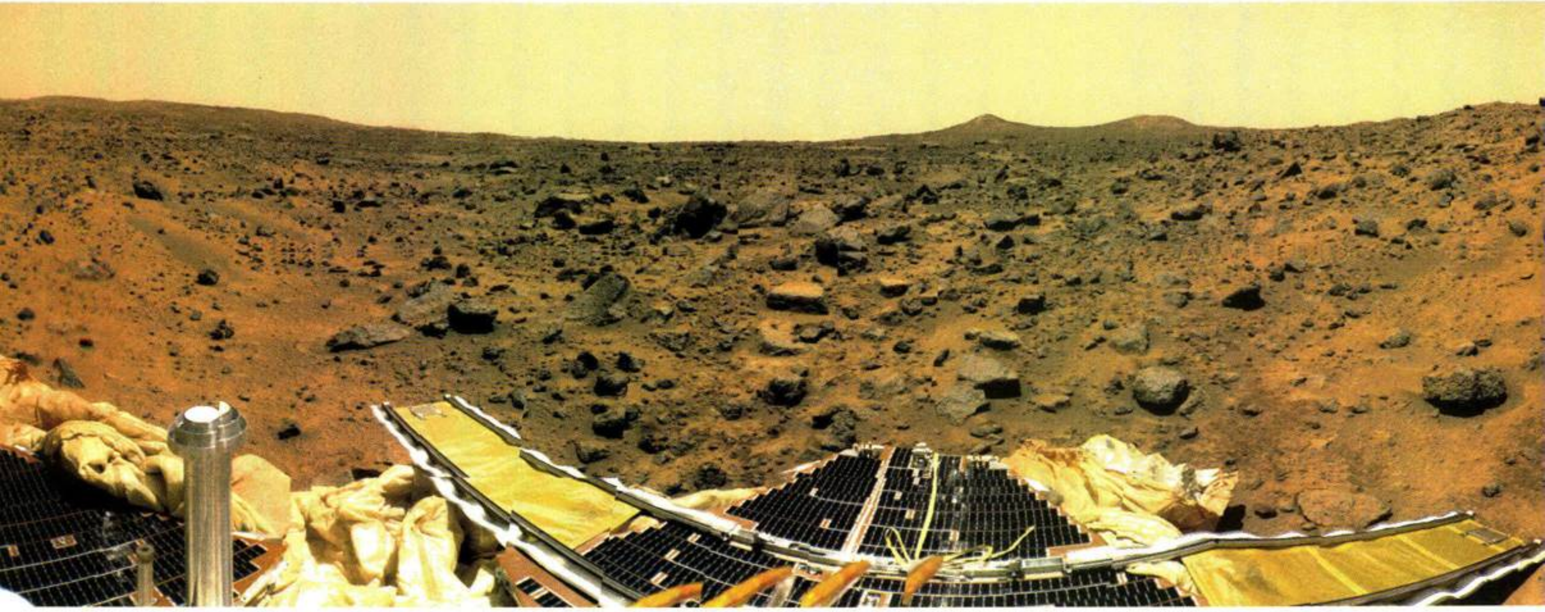


Athéna Coustenis (Paris Observatory), et al.

By looking at infrared wavelengths with adaptive optics, the European Southern Observatory's 3.6-meter telescope imaged surface features on Saturn's cloud-enshrouded moon Titan.

RED ROVER

by Robert Naeye



This 360° panorama shows the view of the Ares Vallis floodplain as imaged by the Pathfinder lander, which has been named the Carl Sagan Memorial Station. The rise at the far left is a crater rim. The Twin Peaks, less than a mile away, appear left of center.

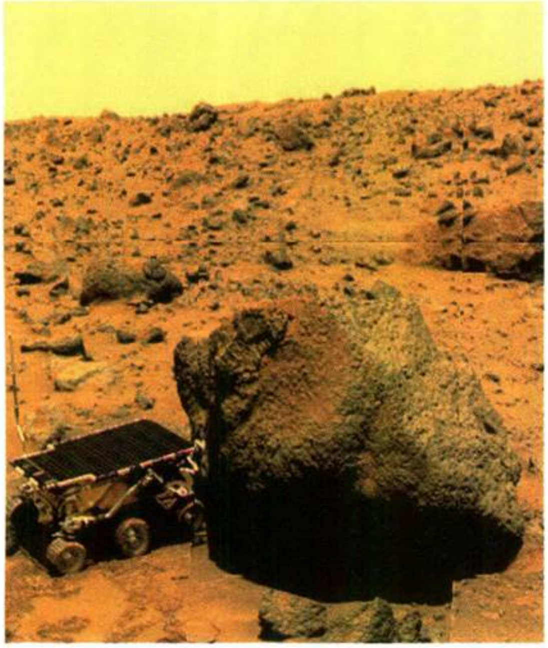
All photos: NASA/JPL

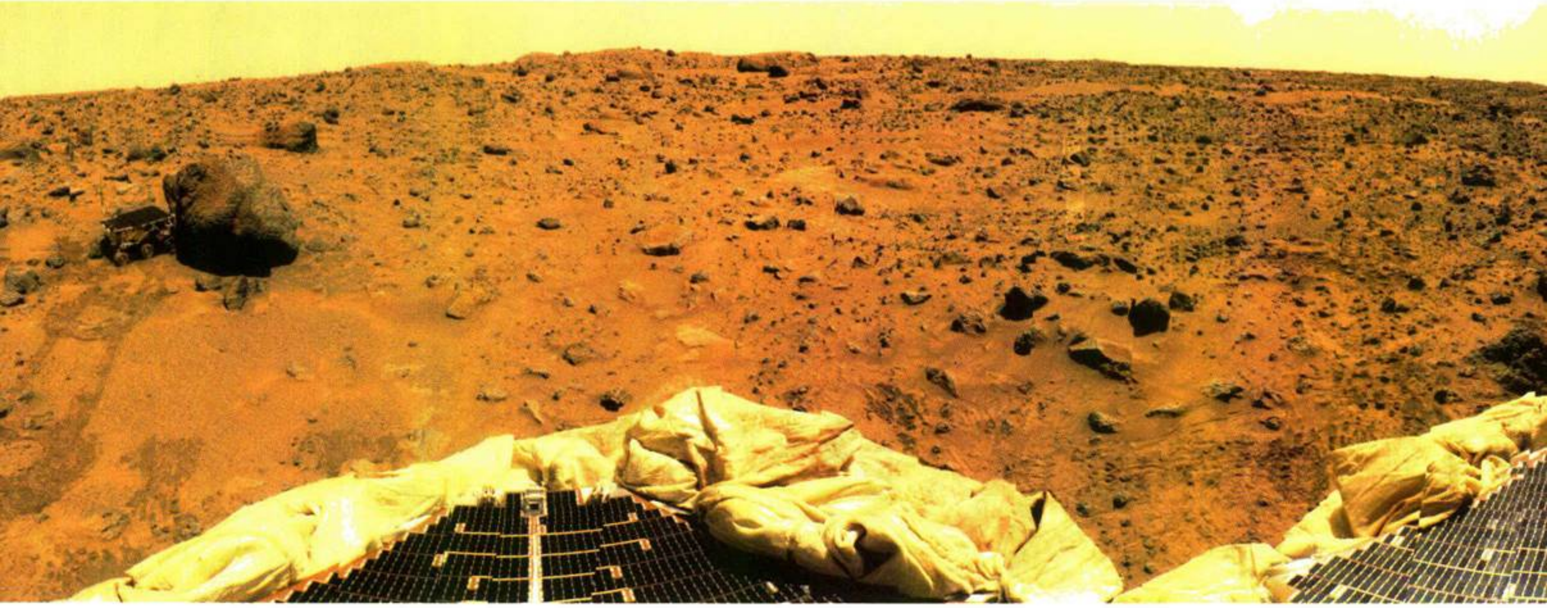
All good things must come to an end. As this issue was going to press, ground controllers at NASA's Jet Propulsion Laboratory had lost touch with Mars Pathfinder for two weeks, and it was uncertain whether communications could be reestablished. The lander and the rover Sojourner returned images and data from the martian surface for more than two months, considerably longer than their designed one-month and one-week minimum lifetimes.

Nevertheless, scientists will be disappointed if communications cannot be reestablished. They had hoped to get several more months of data from the rover and perhaps a year's worth of data from the lander. "We're not ready to concede defeat," says flight system manager Brian Muirhead of JPL, who added, "We'll certainly be disappointed if this mission is over, but we have exceeded our expectations quite a bit, and we got more science than we originally planned. But there was also a lot more to discover at this site."

Project scientist Matt Golombek of JPL says the early scientific analysis has provided three major surprises. First, scientists have been stunned by the high silica content of two of the eight rocks analyzed by Sojourner's alpha proton x-ray spectrometer (APXS). The two rocks, Barnacle Bill and Shark, appear to be very similar in composition to the terrestrial lava andesite, which is rich in silica.

Analysis of the 12 known meteorites from Mars and images from the Viking orbiters gave no indication that martian rocks would have such a high silica content. Rocks with this much silica probably hardened slowly over time so that the heavier,





Sojourner's analysis of Yogi (top left) found it to be similar to basalt, a common volcanic rock on Earth. Sojourner's camera imaged a boulder called Chimp (top right). Wind-blown soil features can be seen next to foreground pebbles. Wind is now the dominant force shaping the surface.

darker minerals (which are richer in iron and magnesium) crystallized first, leaving the lighter silica behind. "It's what we call differentiation," says Golombek, "it's like taking unhomogenized milk and letting the cream rise to the top."

Mars probably had more active crustal processes than scientists had expected for this amount of differentiation to have taken place. Because internal heat drives geological activity, and small planets such as Mars lose their internal heat faster than larger ones, scientists expected Mars to be more similar to the geologically dead moon than the still-active Earth. "We had no idea that these sorts of processes occurred on Mars," says Golombek. "There's definitely a more complicated history than we originally thought."

Cornell University planetary astronomer Jim Bell cautions, however, that weathering processes by the martian atmosphere may form a silica-rich rind on some martian rocks. "APXS doesn't measure deeply into the rock, so the high silica may not be representative of the entire rock," he says.

The second major surprise concerns the variability of Mars's thin atmosphere. "Viking got some great data," says Bell, "but it could only make measurements at less frequent intervals, whereas Pathfinder data come in every few seconds, so you really see the fine structure of the weather." Temperatures can plunge 40° F (22° C) in a matter of minutes, and the mercury can plummet 15° F (8° C) just a few feet above ground. "It means that if you were standing on Mars in the middle of a summer day, your toes would be at room temperature and your eyes would be 10° or 15° F cooler," says atmospheric scientist Tim Schofield of JPL. "You see this contrast in desert areas on Earth, but the contrast is not as marked as it is on Mars."

As Schofield explains, the sun warms the surface directly, but Mars's thin atmosphere does a poor job of retaining heat. It takes less effort to change the temperature on Mars because the atmosphere is thin and there are no oceans to provide inertia against rapid temperature fluctuations.

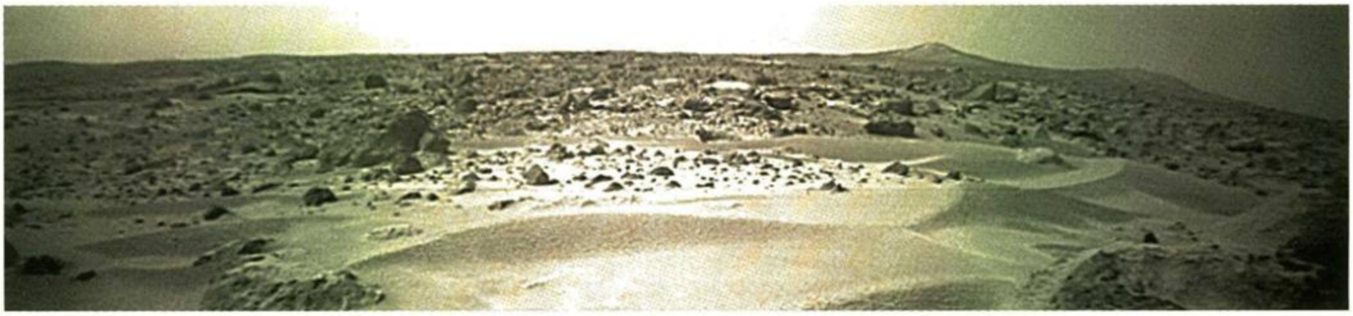
While temperatures can fluctuate wildly, the broad weather patterns recorded by Pathfinder are similar to those recorded by Viking 1 about 600 miles to the west, at nearly the same latitude. The Pathfinder site in Ares Vallis, however, is about 20° F (11° C) warmer. "Because the Pathfinder site is darker than the Viking 1 site, the ground absorbs more solar heat in the day and hangs onto the heat better, and that keeps the surface and atmosphere warmer at night," says Schofield.

Pathfinder provides 100 times better resolution when recording atmospheric pressure than Viking. While Mars has two pressure maxima and minima per day, the overall pressure at the Pathfinder site has been gradually rising as autumn approaches. The record high is only 7.15 millibars, the pressure at a stratospheric altitude of 20 miles on Earth.

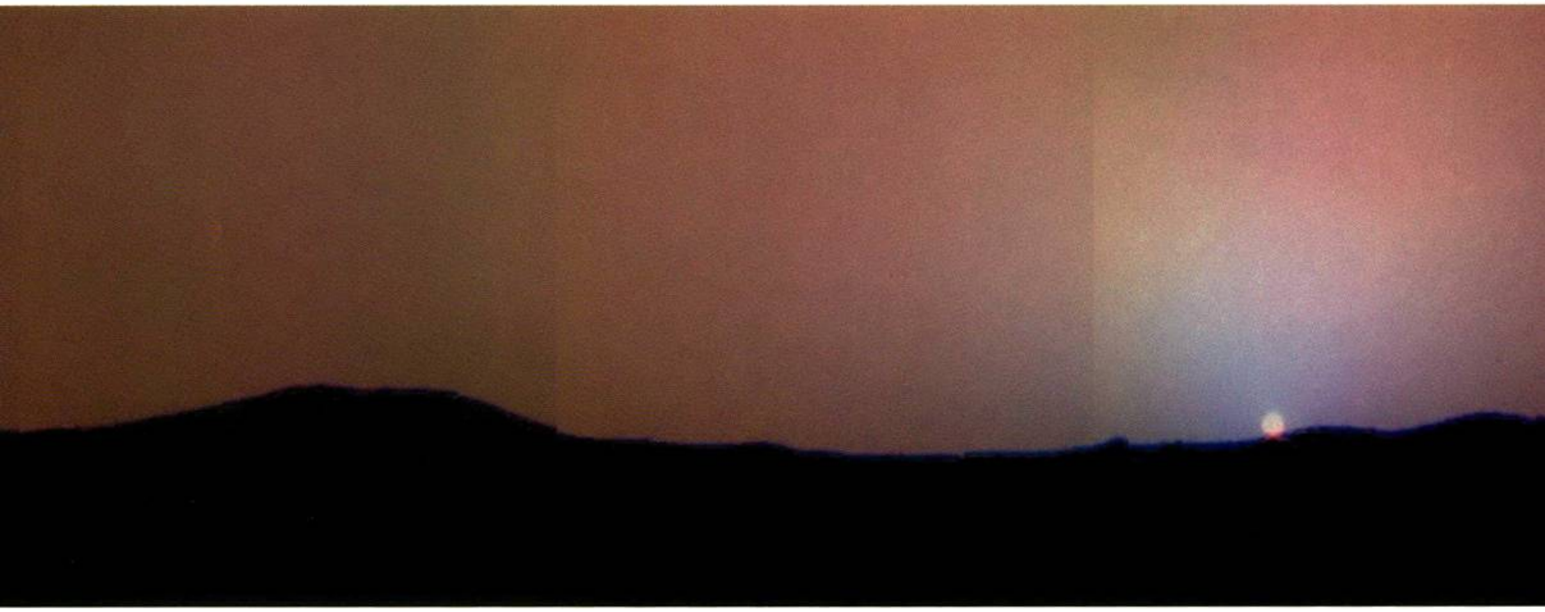
According to Golombek, the third major surprise is the lack of surprises. "From a variety of remote sensing data from the Viking orbiters, we were able to predict what the surface would look like, and that's nothing short of spectacular. From the highest resolution orbital imaging, we could see objects the size of football fields. Yet we were concerned about what the surface would look like on the meter scale."

Bell points to one other surprise: "We're realizing how much the color of the sky affects our perception of the color of the rocks and soil. The martian sky is very red, so it influences everything. If you look at a rock, you're seeing the natural color of the rock multiplied by all this red light that's scattering on it from dust suspended in the atmosphere. You have to very carefully model and subtract that effect if you want to understand the true inherent color of the surface. The colors shown by the Pathfinder imager are very close to the color you would see if you were standing on Mars. But if you brought these rocks back to Earth, they would look very different under our blue sky."

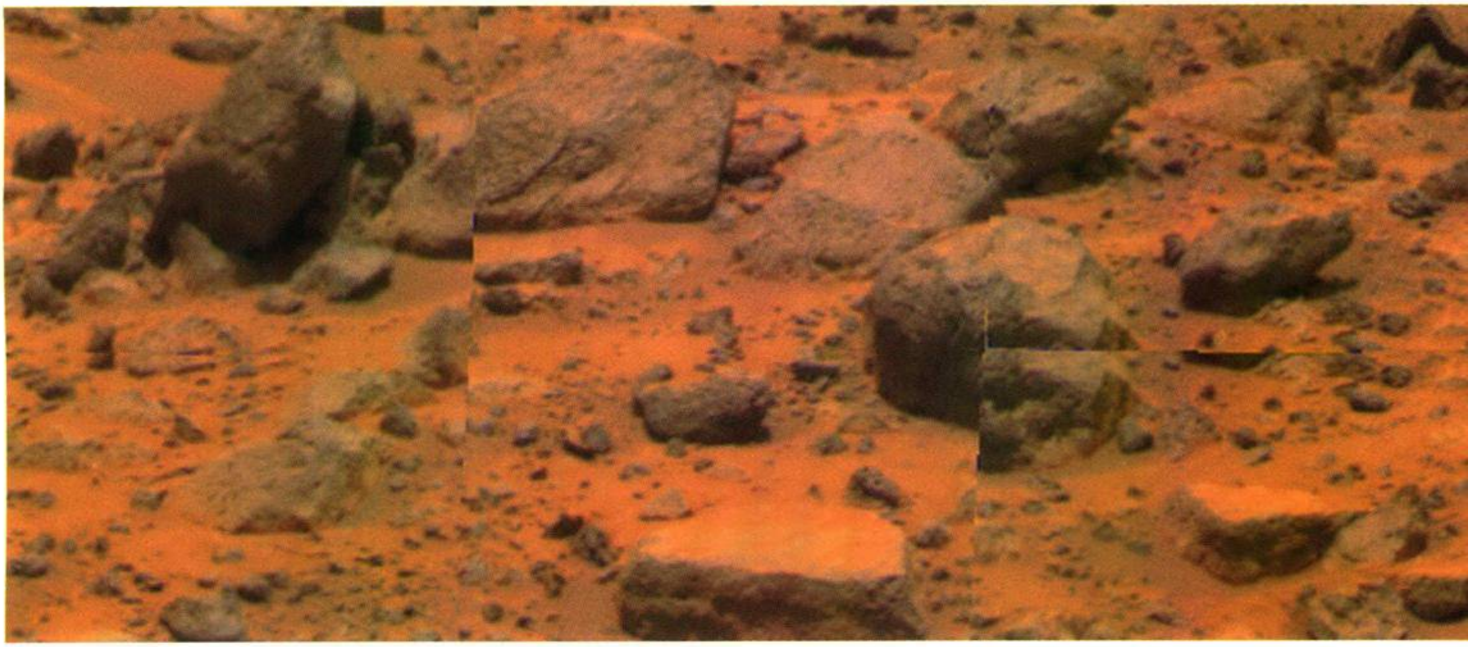
While scientists knew from Viking orbiter images that a vast flood or succession of floods once flowed through Ares Vallis, Pathfinder's images provide spectacular confirmation. Water-scoured pebbles, undulating terrain, and fine-grained sand all bear the hallmarks of running water. "We see very clear evidence that liquid water was stable at one time in Mars's past," says Golombek.

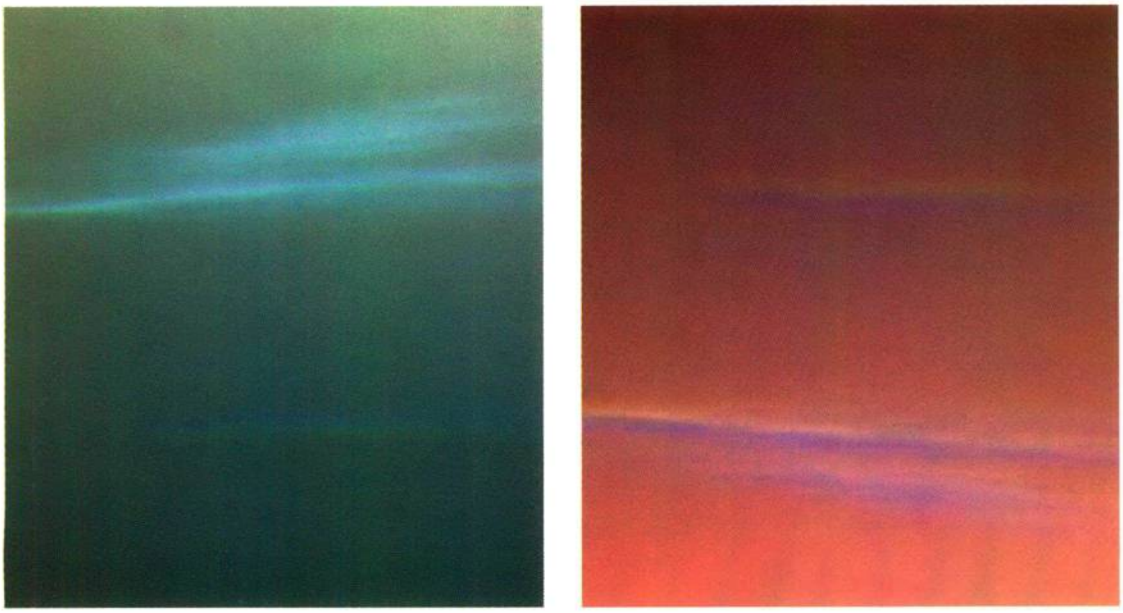


This rover image of sand dunes behind the Rock Garden captures a perspective not visible from the lander.



This near-true color image shows a lovely sunset on the lander's 24th day on Mars. The sun was overexposed; it would appear white or slightly bluish. The sky stays bright for two hours after sunset due to sunlight scattering off of high-altitude dust particles.





The tilt of rocks in the Rock Garden (above) indicates the direction of flood waters. Both sky images (left) are true color. The image on the far left was taken at 5:13 a.m. local time. The image to the near left was taken 40 minutes before sunrise. The blue clouds in both images contain water ice. They probably formed during the night and are 10 miles high.

Bell says most of the immediate scientific objectives were achieved but that scientists were hoping to see the mission move into a new phase: from site characterization to long-term monitoring. The Pathfinder site in the north subtropics is moving into autumn. As Mars's south polar ice cap begins receiving more sunlight, some of its frozen carbon dioxide will evaporate. If the pattern seen by Viking 1 repeated itself, atmospheric pressure at the Pathfinder site would increase 20 to 30 percent and dust storms would kick up. Scientists wanted to learn how the weather changed and how the surface and atmosphere interacted.

Pathfinder, as its name implies, is paving the way for more ambitious missions, including the next rover mission, scheduled to land in January 2002. While Pathfinder wasn't designed to look for life, the low-cost mission has allowed engineers to test new techniques and technologies, which eventually may enable future landers and rovers to answer the question of whether or not Mars once harbored living creatures. "We didn't go there to look for life," stresses Golombek. "The idea was to go to this catastrophic flood channel where we can look at a variety of different materials to learn what the early environment on Mars was. Pathfinder is a first teensy-weensy step in this long-term Mars exploration program whose goal it is to ask and hopefully answer such a weighty and important question."

Even if the mission has come to an end, it has to be termed a spectacular success. Says Golombek, "The data we've obtained will be looked at for years and years. We've been working on the Viking data for 20 years and there's no reason to expect we can't do that for Pathfinder." ■

NASA'S NEXT

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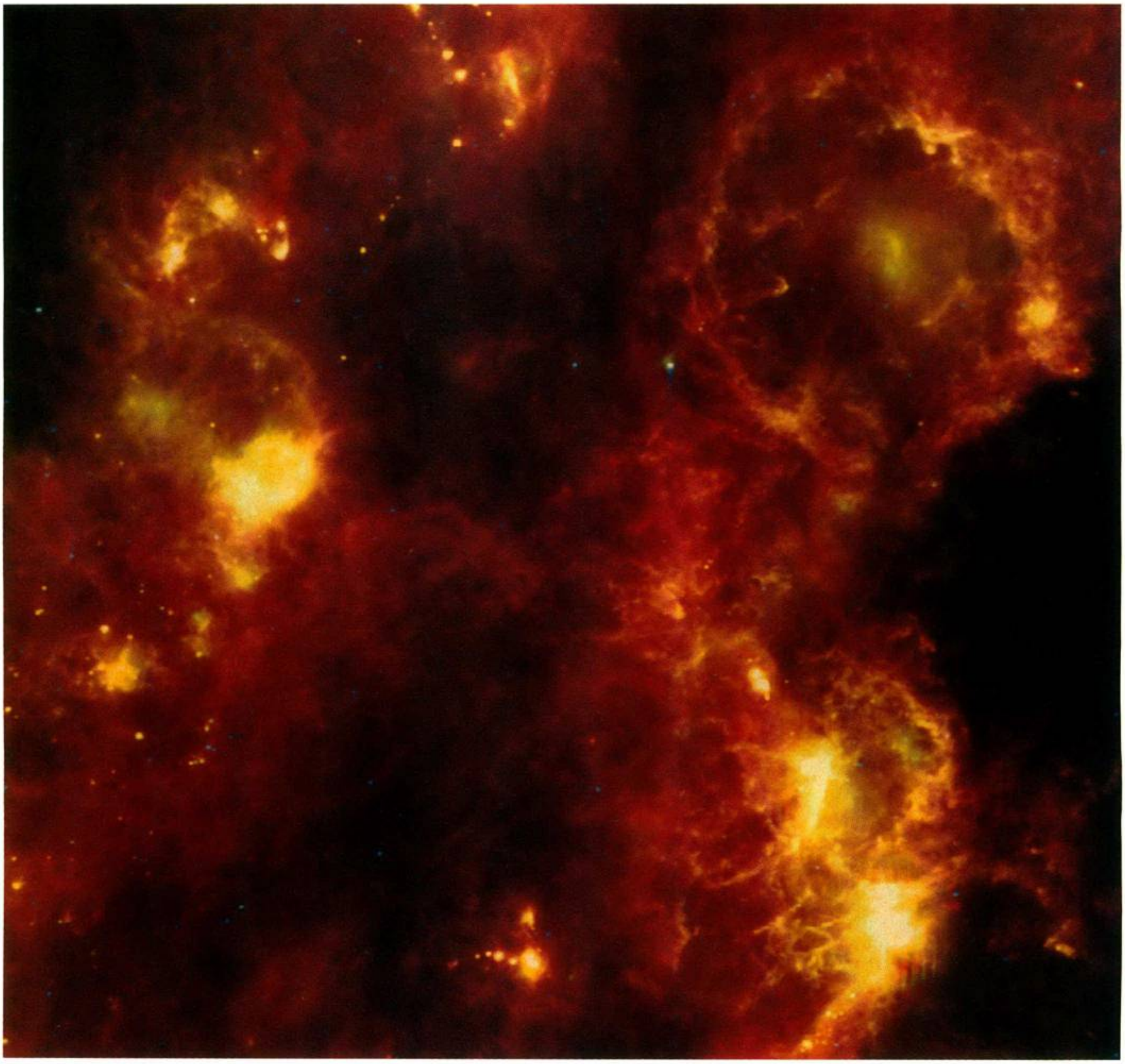


Two new space telescopes will probe deep into the x-ray and infrared universe.

by Ray Jayawardhana

servatories

BACK IN THE 1970S, NASA SCIENTISTS CONCEIVED a suite of four large satellites called the "Great Observatories" to cover most of the electromagnetic spectrum. These satellites would use the most advanced detectors ever built to study the faintest and farthest objects in unprecedented detail. Two of the four Great Observatories, the Hubble Space Telescope and the Compton Gamma Ray Observatory, are already in orbit and have more than lived up to their promise.

Meanwhile, work proceeds on the final two Great Observatories. The $1.3-billion Advanced X-ray Astrophysics Facility (AXAF) is scheduled to launch in August 1998, and detailed design work is about to begin on the $460-million Space Infrared Telescope Facility (SIRTF).

Those who had this grand vision have had to grapple with the realities of NASA's shrinking budget and Congress's distaste for multi-billion-dollar space missions. NASA has reduced the size and scope of both AXAF and SIRTF to bring down costs, while retaining sufficient scientific capabilities to make breakthrough discoveries possible. The result: two leaner, meaner missions that are capable of achieving most of their original objectives at less than half the price.

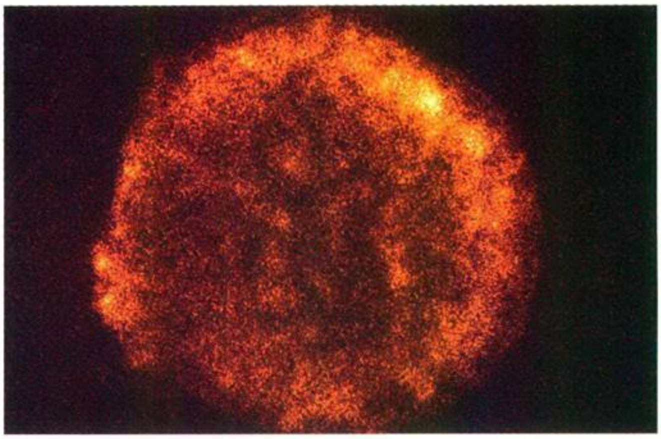
Looking for Black Holes

AXAF will be observing x rays, high-energy photons emitted by violent processes such as stellar explosions and gas swirling into black holes. Due to their high energy, x rays in large doses are harmful for life, which is why medical science is developing alternatives to x ray imaging. Fortunately, molecules in Earth's atmosphere absorb x rays from space before they reach the surface. So to observe x rays, astronomers must place telescopes above the atmosphere.

AXAF is the American follow-up to the Einstein Observatory, a satellite-borne x-ray telescope launched in 1978. The more recent German satellite ROSAT, sensitive to low-energy, or "soft," x rays, discovered many intriguing objects and phenomena. The Japanese x-ray satellite ASCA, currently in orbit, is mostly used to obtain spectra since its image quality is poor.

Originally designed to carry a high-resolution mirror and three imaging and spectroscopic instruments, AXAF has been re-designed several times in recent years. In 1992, it was split into two separate missions — AXAF-I for imaging and AXAF-S for spectroscopy — so that each could be launched by a small rocket rather than a space shuttle, thus reducing the costs. But due to budget pressures, NASA has had to scrap AXAF-S. AXAF-I was subsequently renamed AXAF.

The constellation Orion looks very different when viewed in infrared light. SIRTF will take even better images than this. NASA



ROSAT

If our eyes could see x rays, this is what Tycho's supernova remnant would look like. The image was taken by the ROSAT x-ray satellite.

AXAF's mirrors are very different from those in optical telescopes. Because of their high energies, x-ray photons pierce a mirror like bullets penetrate tissue paper. So x-ray telescopes employ a series of mirrors that look like glass barrels, aligned almost parallel to incoming photons. These cylindrical mirrors have inner surfaces finely polished to precise geometric shapes. X rays enter the front of the telescope and reflect off the inner surfaces of the mirrors at grazing angles, almost like a stone skipping over water, finally coming to a focus behind the mirrors. The mirrors come in four pairs, each pair nested inside the next larger set so that the collecting area of the telescope is as large as possible.

AXAF will have 10 times better angular resolution and 100 times higher imaging sensitivity than the Einstein Observatory. What's more, AXAF is designed to have three times the collecting area of Einstein at low energies, and it is also sensitive to a much larger range of photon energies than either Einstein or ROSAT. For example, AXAF will have considerable collecting area in the higher energy range of strong iron emission lines emitted by many astronomical sources. Astronomers can use these iron lines to probe the inner engine of active galaxies. AXAF is expected to detect active galaxies and quasars 100 times fainter than those observed by Einstein, thus looking much farther out in space and back in time. AXAF will thus prove whether or not the collective emission from these previously unresolved faint sources make up most of the mysterious, diffuse x-ray background, which astronomers discovered in 1962 in a pioneering rocket-borne experiment.

AXAF will be able to detect hot, massive stars in the Magellanic Clouds and determine the temperature, velocity, and density of their powerful winds. It will also map the distribution of different elements such as silicon, iron, and sulfur in supernova remnants in our galaxy and the Andromeda Galaxy (M31). "AXAF will allow us to make major advances toward understanding how exploding stars create and disperse many of the elements necessary for new solar systems and life itself," says Harvey Tananbaum, director of the AXAF Science Center.

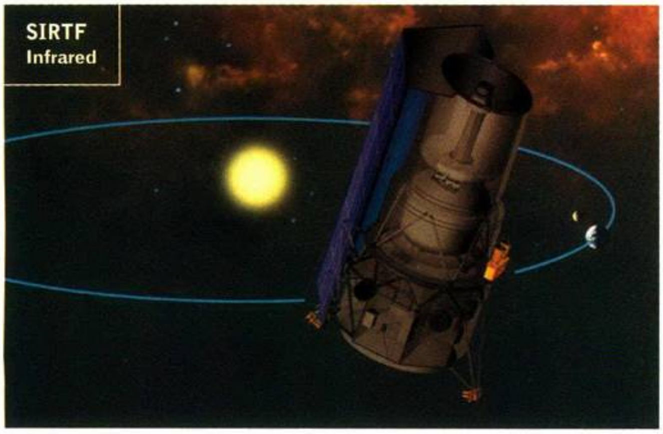
Because higher energy x rays penetrate gas and dust, AXAF will easily see emission from the galactic center. In addition, AXAF can search for and monitor bright x-ray sources, such as neutron stars or black holes accreting matter in our galaxy and hundreds of other nearby galaxies.

Clusters of galaxies, which contain x-ray emitting gas at temperatures of some 10 million kelvins will be another target. AXAF observations will help scientists determine the distribution of all matter, including dark matter, within distant clusters and it will measure cluster redshifts (which yield their distances) using the iron emission line.

So far, AXAF's construction, managed by the Marshall Space Flight Center in Huntsville, Alabama, is proceeding smoothly and well ahead of schedule. Polishing of the telescope's eight mirrors was completed in early 1995, and the major step of aligning and testing all of the flight optics and detectors together took place last spring. Barring any unforeseen problems, the space shuttle Columbia will launch AXAF in August into a highly elliptical Earth orbit which will allow uninterrupted observing intervals of up to 24 hours.

The Infrared Universe

SIRTF will observe infrared light, which is emitted by warm objects such as your body (which is why soldiers use infrared goggles to see in the dark). Unlike x rays, some infrared photons can make it to Earth's surface and can be observed at high-altitude observatories. But as SIRTF project scientist Michael Werner of JPL notes, "The foreground emission from the atmosphere and a warm telescope makes infrared astronomy from the ground like doing optical astronomy in broad daylight. SIRTF will allow us to work at night."



NASA

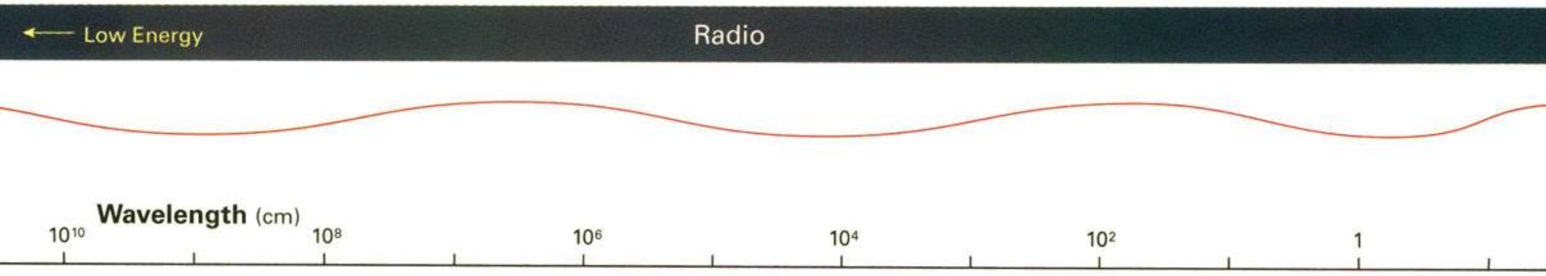
SIRTF will build on the heritage of two successful infrared satellites of the 1980s. The Infrared Astronomical Satellite (IRAS), launched in 1983, conducted an all-sky survey across a broad swath of the infrared spectrum, cataloging hundreds of thousands of infrared sources. During its 10-month lifetime, IRAS observed many exciting objects near and far: asteroids, comets, and tenuous dust in our solar system; newborn stars shrouded in cocoons of dust; protoplanetary disks around nearby stars; and thousands of "starburst" galaxies which owe their brilliance to hordes of massive young stars. SIRTF will also be guided by results of the European Space Agency's Infrared Space Observatory (ISO), a smaller infrared satellite launched in November 1996.

HUBBLE
Visible

NASA

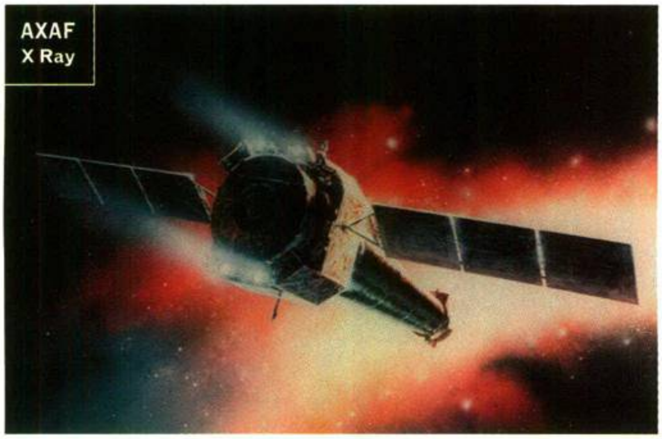
Since its conception some 15 years ago, SIRTF has undergone several major design changes to scale down the cost, such as having its minimum lifetime reduced from five years to 2.5. Like many other missions, the old SIRTF was to be launched into low-Earth orbit by the space shuttle. Later, mission planners considered the possibility of placing it in a higher orbit using a booster rocket. The real breakthrough in thinking occurred when they came up with the idea of putting the satellite into an orbit around the sun rather than Earth. Ironically, it is easier to launch a satellite into solar orbit than into Earth orbit. To place a satellite into Earth orbit, it's necessary to fire the engines twice — once to get into orbit, and once to make the orbit circular rather than elliptical. A solar orbit, on the other hand, can be achieved with a single firing, making it possible to use a smaller, cheaper Delta II rocket instead of a giant Titan.

Electromagnetic Spectrum



As Giovanni Fazio of the Smithsonian Astrophysical Observatory points out, the planned solar orbit (the spacecraft will trail Earth in its orbit by some 60 million miles) has another significant advantage: It isolates the spacecraft from the blinding effect of Earth's infrared emission, allowing for longer periods of observing. "The solar orbit allows you to observe essentially 24 hours a day," notes Fazio.

SIRTF's advanced technology will make it 10,000 times more sensitive than IRAS. The three scientific instruments on SIRTF — a camera, a spectrometer, and a photometer — will span a broad range of wavelengths from the near to the far infrared. They will employ infrared CCD arrays to provide imaging with fields of view as large as 5 by 5 arcminutes. To achieve the full potential of these devices, SIRTF will be cooled below four kelvins with liquid helium; that prevents the satellite's own heat from interfering with observations.



NASA

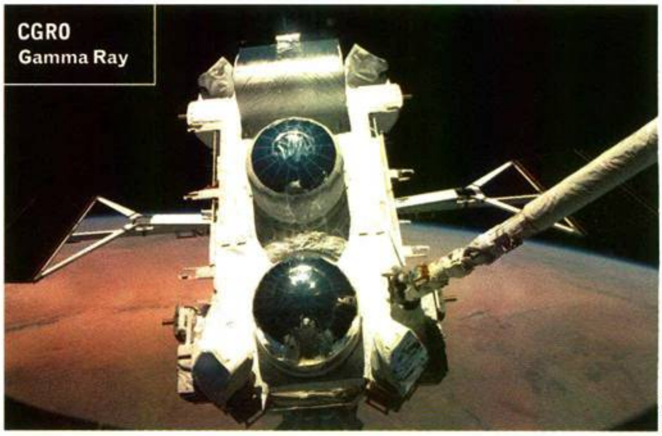
One of IRAS's most exciting discoveries was that several nearby stars such as Vega and Beta Pictoris are surrounded by disks of tiny dust particles. These disks, thought to be debris left over from the formation of planets, absorb visible and ultraviolet light from the parent star and re-radiate it in the infrared. SIRTF will be able to image disks around nearby stars in great detail, searching for possible empty regions swept up by planets, and to determine the disks' composition by obtaining their spectra. SIRTF can also search for debris disks around thousands of other stars, to see how common they are.

Recently, astronomers have confirmed the discovery of a brown dwarf, Gliese 229B, an object too low in mass to sustain nuclear burning but one that radiates in the infrared by releasing gravitational energy as it contracts. SIRTF will be used to search for other brown dwarfs, to determine if they could account for a significant fraction of the dark matter.

In addition to showing that a typical spiral galaxy radiates nearly half of its energy at far-infrared wavelengths, IRAS also discovered a new class of active galaxies called "ultraluminous galaxies" whose energy output approaches that of quasars. SIRTF can detect these galaxies out to large distances — back to the early universe — so it can study their evolution. If they are triggered by violent galaxy interactions and mergers, as some astronomers believe, they must have been more common at earlier times when galaxies were closer together. Deep SIRTF images will also help astronomers probe the early universe and perhaps discover proto-galaxies undergoing an initial burst of star formation.

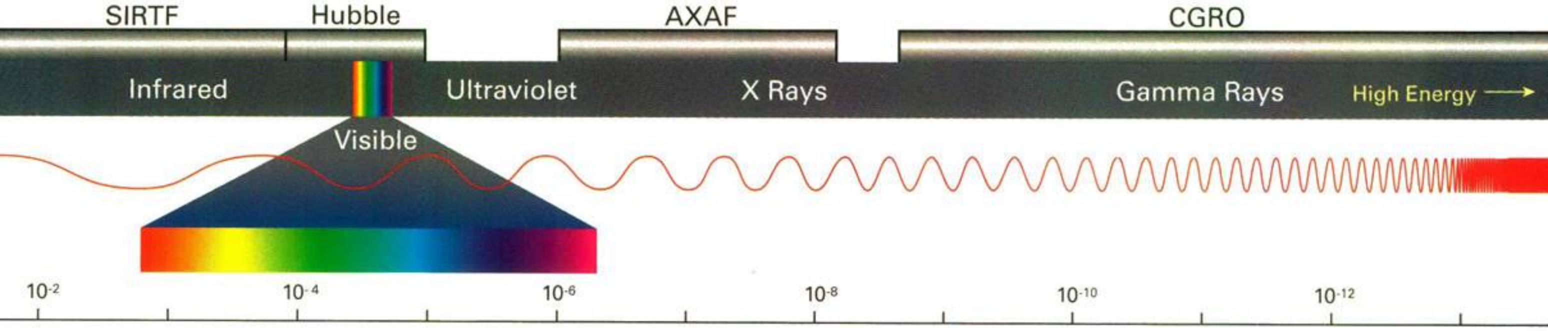
The construction of SIRTF, which is being overseen by NASA's Jet Propulsion Laboratory in Pasadena, California, is scheduled to begin in April 1998 in preparation for launch in December 2001. President Clinton's budget request of $24.9 million for the fiscal year 1997 allowed SIRTF scientists to start detailed mission design in October. Astronomers are anxious to launch SIRTF by 2002 so it will be in operation at the same time as the Hubble Space Telescope and AXAF, allowing detailed follow-up observations at optical and x-ray wavelengths of any new phenomena it discovers in the infrared. As Werner says, "SIRTF combines the power of new infrared detectors with the dark infrared sky of space. It will provide the data we need to begin to understand the birth of planetary systems, stars, and galaxies." ■

Ray Jayawardhana, an astronomy graduate student at Harvard University, studies star formation.



NASA

NASA's four Great Observatories will cover different segments of the electromagnetic spectrum (below). The electromagnetic spectrum encompasses the various wavelengths of light, most of which can't be seen by the human eye. *Astronomy:* Elisabeth Rowan



Celes NAVIGATOR

Robert Burnham Jr., whose monumental book guided millions through the night skies, lost himself in San Diego.

By Tony Ortega

MY SEARCH FOR ROBERT BURNHAM JR. ended on a warm September day under a large pine tree in Point Loma, California. For several weeks I had tried to find the author of *Burnham's Celestial Handbook: An Observer's Guide to the Universe Beyond the Solar System*, and a trail of clues had brought me to a wall covered with marble headstones in Fort Rosecrans National Cemetery.

There, on the bottom row of section 70, rested the marble slab I had been looking for. "Robert Burnham Jr. A1C USAF 1931 1993," it read. The stone said nothing about Burnham's authorship of a monumental book revered by the vast majority of people who ply the night sky with telescopes. Nothing about his years as an astronomer at Lowell Observatory. Nothing about his discovery of six comets. He was simply an Air Force veteran who had been cremated and memorialized with thousands of others.

I lingered at the site for several minutes, wanting to do something meaningful but having no idea what that something might be. Then I left.

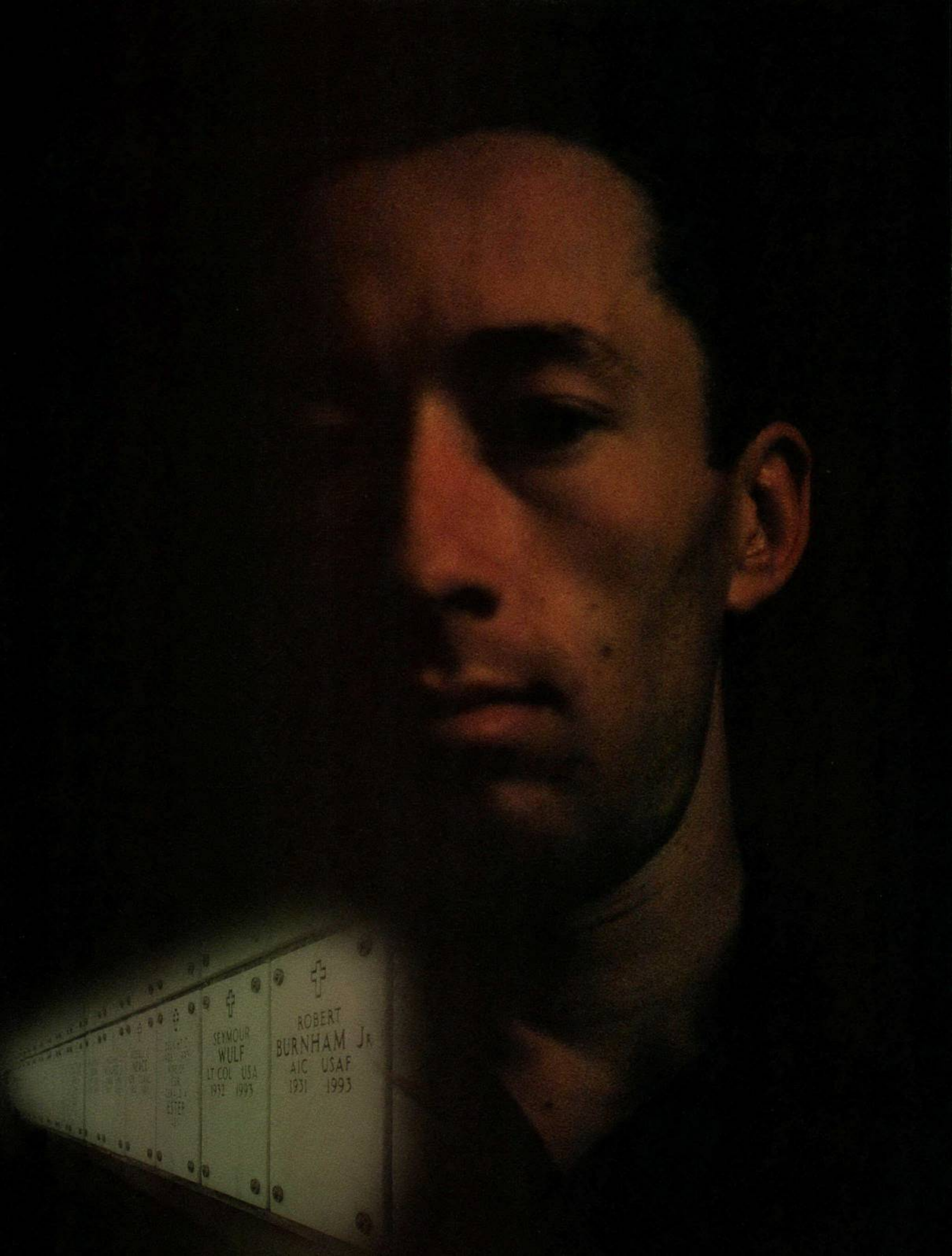
Several days later I wrote what I had learned for the *Phoenix New Times*, where I am a staff writer. Almost

Burnham holds a piece of a meteor that formed Meteor Crater, below. He was buried quietly at Fort Rosecrans National Cemetery in 1993.

METEORITE
FOUND NEAR
CANYON DIABLO
WEIGHT 535LBS.

Courtesy of Viola Courtney

Courtesy of Viola Courtney; inset: Tony Ortega


ROBERT
BURNHAM JR
AIC USAF
1931 1993
SEYMOUR
WULF
LT COL USA
1932 1993
ESTEP

immediately, expressions of shock from astronomers around the world began to arrive. Robert Burnham Jr. had been dead for more than four years, and only a handful of people had known. Some of the *Handbook's* readers were aware that Burnham's fortunes had declined after his employment at Lowell Observatory ended in 1979. Others admitted that they had known nothing at all about the man whose book they knew so well.

Courtesy of Viola Courtney

Robert Burnham Jr. and his mother, Lydia.

He had long been confused with Robert Burnham, who for years was editor of this magazine. That Burnham published frequently during the period the *Celestial Handbook* gained popularity, causing readers to assume that the two were the same.

But Robert Burnham Jr. published almost nothing else besides his *Handbook*, and he shunned publicity. He led an extraordinary, but ultimately tragic, life. The *Celestial Handbook* began as a project he meant for himself, a young Prescott, Arizona, shipping clerk with only a high school education who, in 1955, began taking copious notes as he surveyed the heavens.

Burnham was born in Chicago on June 16, 1931. His family had moved to Prescott in 1940. His sister, Viola Courtney, describes him as an exceedingly shy but brilliant young man who excelled in school. But Burnham didn't seem interested in college and the family could not have afforded to send him, she says. Faced with the Korean War era draft, Burnham joined the Air Force in 1951 and served four years, traveling to places like Saudi Arabia. Afterwards, he came back home to his parents' house and threw himself back into his hobbies.

Only two years later, his "Celestial Survey" — as he called it — had grown to fill six notebooks and 1,200 pages. On the night of October 18, 1957, anxious to use his newest telescope despite its lack of a proper mount, Burnham propped up its tube against the porch railings of his parents' home to examine double stars in Cetus. At 10:30 p.m., Burnham discovered his first comet, Comet Latyshev-Wild-Burnham, an 8th-magnitude object speeding 13° a day as it passed less than a tenth of an astronomical unit from Earth.

The event brought Burnham to the attention of several powerful Arizonans including Senator Barry Goldwater, the conservative who as a Republican ran for the presidency of the United States in 1964. More importantly for Burnham's future, he drew the interest of Henry Giclas, a Lowell Observatory astronomer who had recently launched a proper-motion survey with the 13-inch Pluto discovery telescope. Giclas hired Burnham in February 1958 at a $6,000 salary and the promise of two to three years of employment.

Instead, Burnham and fellow research assistant Norm Thomas would work longer than 20 years together on the survey. By the time it ended in 1979, they had identified 9,000 high-motion stars as well as several comets, 1,500 asteroids, and 2,000 new white dwarf suspects and thousands of variable stars that they simply had no time to study.

Like others, Thomas describes Burnham as shy and reclusive. Only a few times in their close 20-year collaboration did Burnham make the trip down from Mars Hill to Thomas's home.

With his access to Lowell Observatory's resources, Burnham's Celestial Survey quickly became considerably more than the notes of a single amateur astronomer. Burnham could now include more scientific depth and several thousand intriguing photographs.

His inquiries to publishers, however, were rebuffed. So, in 1966, Burnham decided to publish the *Celestial Handbook* himself. Thomas says Burnham was disappointed that Lowell Observatory refused to help in promoting the book. But Henry Giclas says that since Burnham refused to allow Lowell's astronomers to review the manuscript, he couldn't let it be published as an official observatory publication.

Thomas says Burnham resented his colleagues' reaction. "They were afraid that it would be full of errors, and then it turned out to be better than 80 percent of the stuff [published about astronomy] that comes out. The good reviews quieted some people down. That, and the fact that it became quite famous because of the lack of errors."

As Burnham's work at Lowell continued, his *Handbook* became a classic. By 1975, Burnham had secured a deal with Dover Publications Inc. in New York to republish the *Handbook* in three volumes. Three years later, the books appeared. But even as he began to enjoy the benefits of wider publication — and regular royalty checks — Burnham learned that Lowell Observatory planned to fire him.

Norm Thomas says that by 1979 one of the proper motion survey's goals had been met: After photographing small patches of the sky year after year, they had eventually worked their way to the north celestial pole.

By that time, Thomas had completed a master's degree in geology at Northern Arizona University, and it wasn't difficult for the observatory to find other work for him studying asteroids. But Burnham, despite his almost 22 years of service, wasn't so easy to reassign.

In April 1979, Burnham received official notice that his employment would end. The observatory gave him time to prepare: His job would not end until December of that year, and Lowell offered help finding him further employment.

Norm Thomas was exasperated by Burnham's refusal to prepare for his termination.

In December 1979, Burnham packed up his collections and books, rented a large apartment in Flagstaff, and severed his association with Lowell. Rent payments would soon stretch his resources despite the royalty checks from Dover.

Norm Thomas's son Bruce, who had become very close with Burnham, remembers that Burnham was initially optimistic when he left the observatory. He received royalty checks in the mid-four figures every six months, he had begun another writing project — a fantasy novel — which was taking on epic proportions, and he'd rededicated himself to painting and other interests he'd put off.

But that optimism, Thomas says, didn't mask his bitterness at Lowell's termination of him.

Burnham also complained about how Dover Publications marketed the *Handbook*. He told Thomas that the book's narrow audience would pay more than the $8.95 per volume cover price. To his sister he complained about the Astronomy Book Club's deep discounting of the set, telling her that it caused his royalties to drop dramatically.

Other complaints, Thomas says, were less rational. One of Burnham's gripes against Dover was its lack of interest in the fantasy novel he was writing.

In 1982, with the popularity of the *Handbook* probably at its height, an article about Burnham — the only substantial biographical piece about him — appeared in *Astronomy*.

Burnham had interviewed himself for the article.

Arrogant, weird and fascinating, a much longer version of the "interview" resides among Burnham's papers. In the 37-page, single-spaced essay, Burnham delves deeply into his philosophical and political thought. His Eastern approach to nature and a disdain for organized religion and materialism were long-held and characteristic of Burnham. Newer was the sense of frustration that the *Handbook*, considering its scope and popularity, reaped so little compared to books on astrology and other nonsense that commanded million-dollar advances.

Such frustrations about money, Bruce Thomas says, would increasingly consume Burnham.

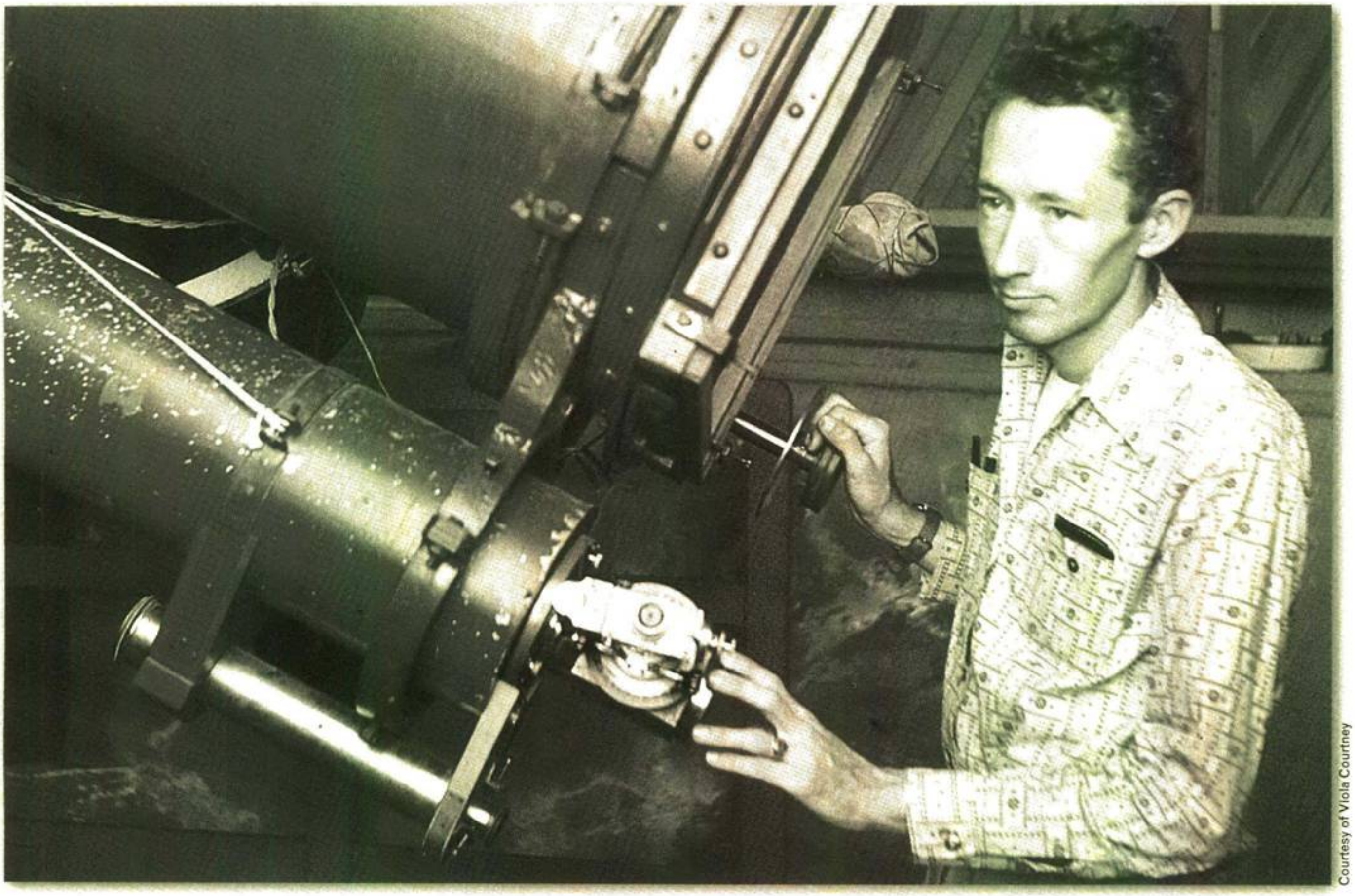
In December 1983, Burnham spotted a reference to himself in an issue of *Sky & Telescope*. columnist George Lovi wished that more authors would show the dedication and drive of Burnham and several others. Burnham had to respond; his letter appeared five months later.

"Lovi . . . lamented the fact that so few people display the dedication needed to accomplish such a large project. This is hardly surprising when the rewards offered by our society can be so small.

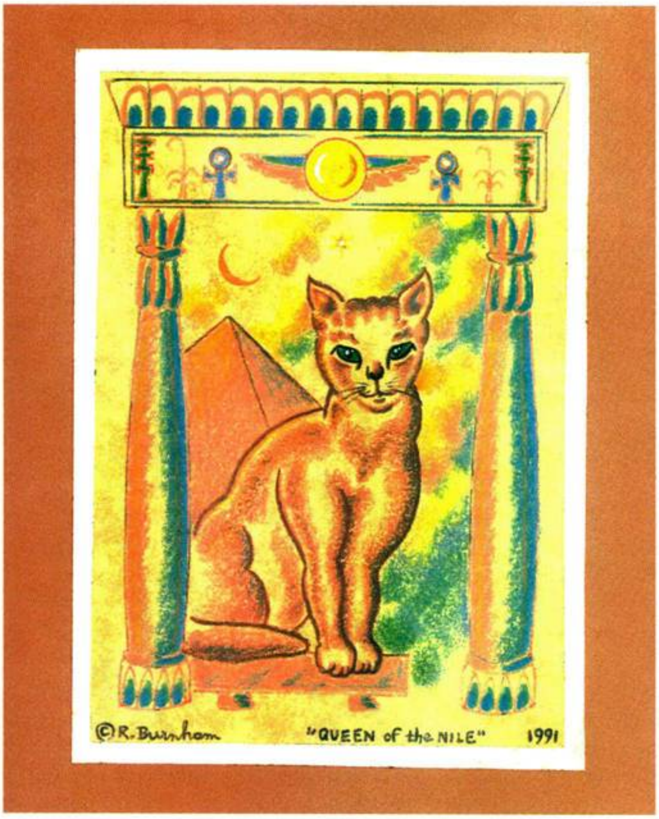
"I have devoted over two decades of my life to astronomy, and my *Celestial Handbook* has been called a modern classic. I am the discoverer of six comets, not to mention thousands of new proper-motion stars, which my colleagues and I found during a 21-year proper-motion survey at Lowell Observatory. As a result of all these accomplishments my income has rarely risen much above the poverty level. . . ."

If Burnham, who always kept so assiduously to himself, was uncertain about the impact his books had had on others,

Burnham at work in Lowell Observatory.



Courtesy of Viola Courtney



Courtesy of Viola Courtney

Burnham spent his last seven years in San Diego selling cat paintings — from a park bench near the Reuben H. Fleet Space Theater.

he would know in no uncertain terms after the responses to his letter began to arrive.

Wrote one devotee: "I am on my second set of these books — the first set wore out from heavy use. In my library of over 1,200 books, this set is my most prized possession. . ."

Author Timothy Ferris also had written to Burnham about his admiration for the *Handbook*: "I cannot begin to tell you how much pleasure these volumes have brought me, not to mention their great value as sources of information. I should like, as a token of my appreciation, to send you a copy of the new edition of my book *Galaxies*. . . . I hope you'll enjoy the book at least a fraction as much as I have yours."

Another letter writer, Louis Lyell of Jackson, Mississippi, wrote Burnham about an observatory he had helped build at a private school and about the school's need for an astronomy teacher. The job seemed custom-made for Burnham, who enjoyed talking to young people about science more than anything else. Lyell says he never got a reply. Instead, Burnham sank further into bitterness and obsession about money. Then, in July 1985, he vanished.

Seven weeks later, a Newport Beach, California, policeman noticed him walking aimlessly on the beach. He was wearing a long-sleeve shirt and pants, but his feet were bare, and they were covered with second-degree burns from exposure to the sun. He was taken to a hospital for treatment, then released to a shelter.

Courtney brought him home and installed him in her one-bedroom mobile home in north Phoenix and nursed him. "He had no memory of how he came to Newport Beach, no idea of reality during the prior [seven]-week period. All he remembered were . . . hallucinations," Courtney says.

Whatever had caused Burnham to lose a grip on reality seemed to have passed. But Courtney says Burnham admitted to her that he feared ending up in a mental institution. He refused her suggestion to seek an examination. "Perhaps he left Phoenix because he was afraid I would keep pushing to get him some kind of counseling," she says.

Early in June, Burnham left again without warning. Courtney would learn that on May 30, 1986, Burnham had withdrawn the last $20 from his bank account. He left with the money, the clothes on his back, and his social security card. For the last seven years of his life, Burnham apparently took up residence in an inexpensive hotel in San Diego and sold paintings of cats in nearby Balboa Park.

Workers at Reuben H. Fleet Space Theater remember him but didn't know his identity. Dennis Mammana, the planetarium's astronomer, remembers seeing Burnham sitting on the same bench, day after day.

Asked if he knew the man was the author of *Burnham's Celestial Handbook*, Mammana replies: "He couldn't have been. Robert Burnham, the man who wrote the *Celestial Handbook*, was an editor at *Astronomy* magazine at the time."

When he is told that he has made the common mistake of confusing the two writers — that there were in fact two Robert Burnhams, and the author of the *Handbook* had ended up sitting on a park bench outside his planetarium — Mammana sounds dismayed.

"Somebody had told me that he claimed to be Robert Burnham. This is just incredible. I'm sure no one believed him. You don't expect that someone in that condition would be capable of producing such a work. The book is on every astronomer's shelf. What a resource he could have been."

In the fall of 1991, Bruce Thomas stumbled upon Burnham. "It was awkward. . . . He said he was just taking it easy and was still getting checks from Dover," Thomas says.

A few days after Christmas 1991, Norm Thomas visited his son, and the two of them went to the park to reunite the two old Lowell astronomers. Norm Thomas told Burnham that he planned to name an asteroid after him. An asteroid already carried the name Burnhamia, named after turn of the century astronomer S. W. Burnham, but Thomas remembered that Burnham had told him that in Germany, his father's parents had gone by the name Bernheim. So, that's the name Thomas planned to use, to honor his co-worker.

"Bob seemed happy about that," Bruce Thomas says.

Bruce Thomas would make several more visits to the park looking for Burnham. Each time, he looked in vain.

On March 9, 1993, Robert Burnham entered San Diego's Mercy Hospital. His death certificate indicates that he was suffering from congestive heart failure, the result of an earlier heart attack. Burnham had a host of other ailments, as well — a blood clot, gangrene in one foot, pneumonia — all probably related to the gradual deterioration of his heart.

At 6:03 p.m. on March 20, his heart stopped beating.

San Diego County administrators classified him as an indigent veteran and oversaw his cremation at Fort Rosecrans National Cemetery. A headstone memorializes him. Above his name is a cross, put there at the request of a San Diego County public administrator. It seems inappropriate.

"Is there any religion that invites skepticism, or a freely inquiring type of mind? The scientist is free to say to his colleagues: 'Gentlemen, new findings have made it necessary to revise some of our ideas.' Have you ever heard a minister make such an announcement to his flock?" Burnham said.

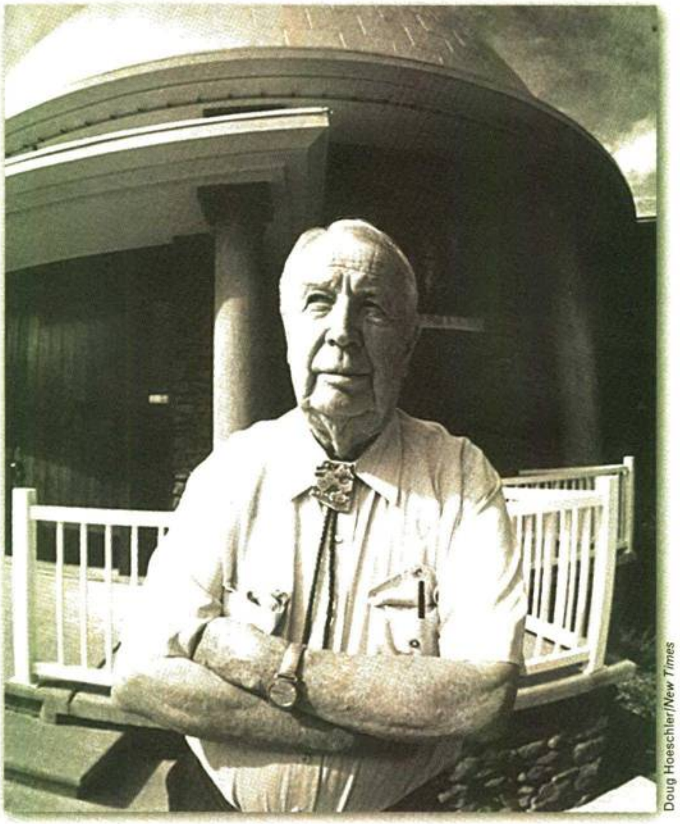
But Bruce Thomas cautions against making too much of the symbol on Burnham's memorial. "I'm sure if you asked him, he would tell you he wouldn't want any kind of headstone, that it was silly."

Thirty years after its first publication, the *Handbook* remains a very popular work, although its use of equinox 1950 coordinates and reliance on poor magnitude estimates, sizes, distances, and a host of other old data dates it. Other material is far behind the latest scientific understanding.

A year ago, Lowell Observatory's Brian Skiff began considering taking on the task of updating Burnham's massive work. Before taking on the challenge of producing a new *Handbook*, he decided he'd better take another look at the book. "I think it's just fantastic."

It was also daunting. Skiff has put the task aside, at least temporarily. He has enough work to do investigating asteroids. And when he's finished observing, he retires to his home: an old cabin that Burnham lived in for the years he worked at Lowell.

Skiff put me in contact with Norm Thomas when I began searching for Robert Burnham. Thomas in turn gave me the clues I needed to find Viola Courtney.


Doug Hoeschler/*New Times*

Henry Giclas hired Burnham to work at Lowell Observatory for two or three years and laid him off after 22 years. Burnham never recovered.

Shortly after my *New Times* article ran, I received a grateful-sounding message. It was from Robert Burnham. Editor of *Astronomy* magazine until 1996, "the other" Burnham has spent most of his adult life explaining to people that he did not write the *Celestial Handbook*.

"Bob and I never met. . . but I felt, ever since starting with the magazine, that we were going to be in and out of each other's shadows. First me in his shadow, when I was an ordinary amateur peering through a telescope and he was a working astronomer at Lowell. And then he kind of fell into my shadow when he left Lowell [and] my career got going."

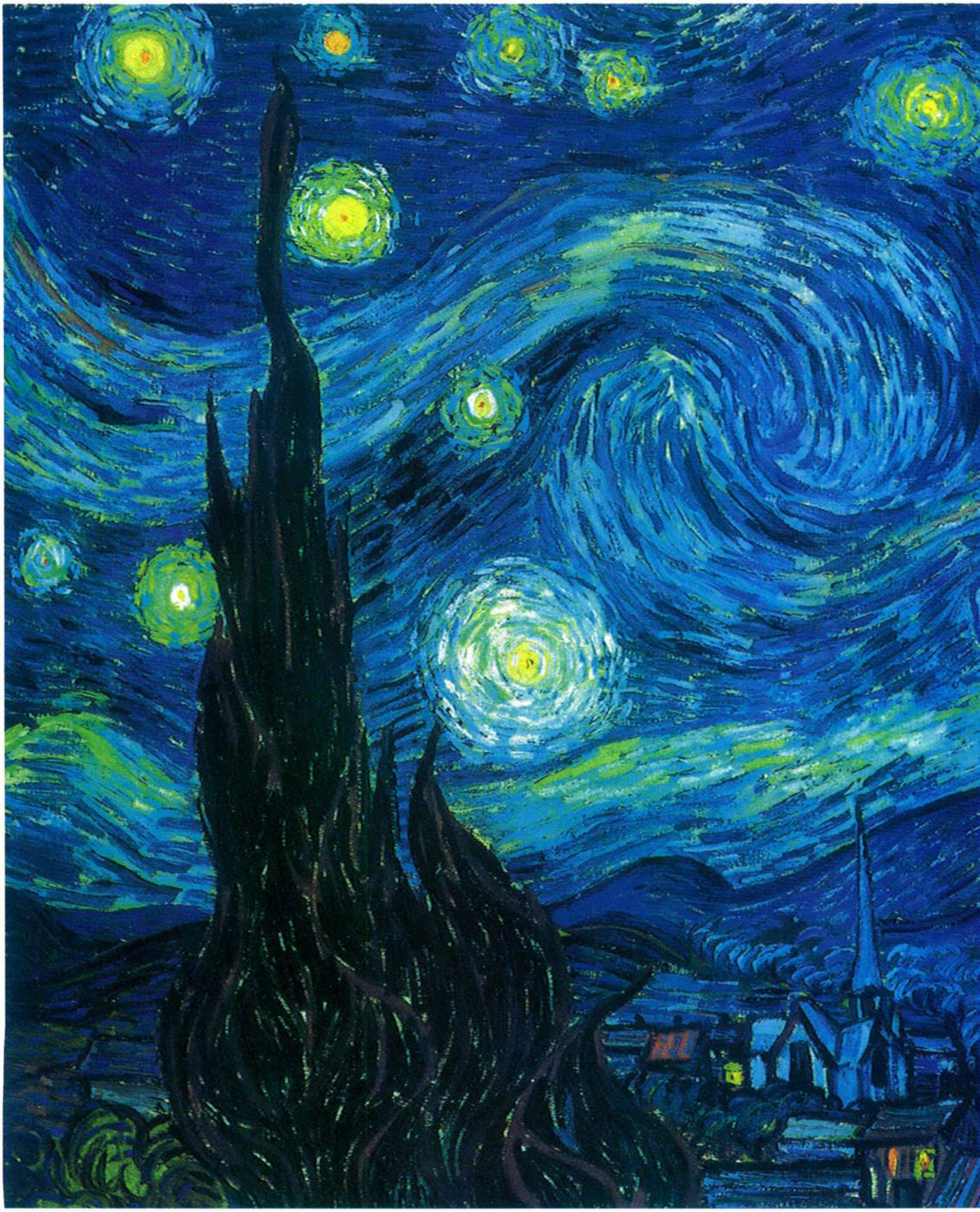
I received other messages from astronomers around the globe. Nearly all of them were compelled to describe how much the *Handbook* had meant to them. Many also remarked at how sad was Burnham's story.

I preferred to remember what had motivated me to find him in the first place: the debt I owed to the man who had taken me to so many places in the universe. ◼

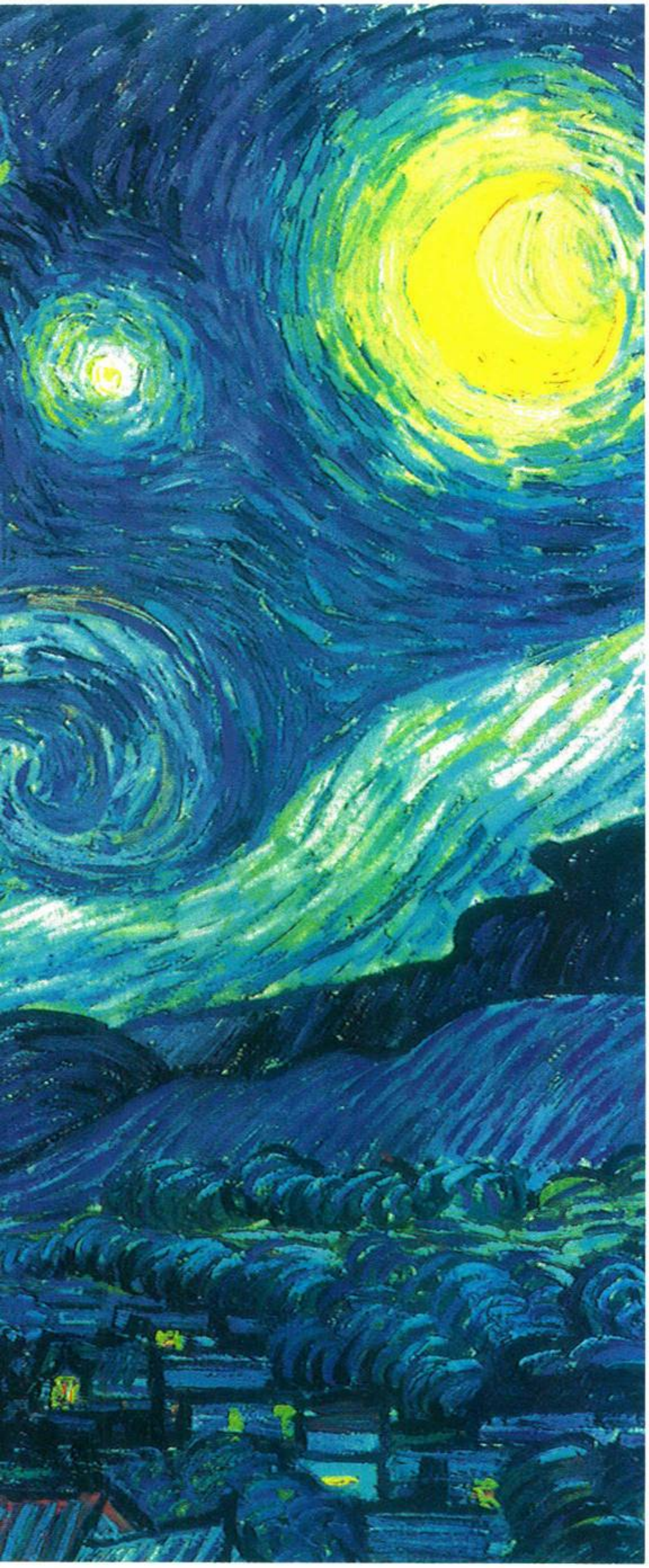
Tony Ortega writes for the Phoenix New Times, *where a story on Robert Burnham Jr. appeared in September. It can be read at www.phoenixnewtimes.com/1997/092697/feature1-1.html.*

Burnham's inner universe mirrored the tumult of Niagra Falls.

Courtesy of Viola Courtney



Vincent Van Gogh. The Starry Night. (1889) Oil on canvas, 29x36 ¼" ©1997 The Museum of Modern Art, New York



How Stars Shine

Great Moments in Astronomy

by James Trefil

Some of astronomy's greatest moments brought incandescent insights, among the greatest the human mind has ever produced. Hubble's realization that the universe was expanding and Copernicus's dream of the moving Earth are two examples. Those insights produced an abrupt change in our conception of humanity and its place in the universe and have been celebrated and explicated many times.

There are, however, other kinds of great moments. These occur when a crucial step is taken toward resolving an old problem, but it is only in retrospect that anyone realizes how important the step was. These moments too have a role to play in changing our understanding of our place in the universe.

In this series of occasional articles, noted author and physicist James Trefil explores some great moments in astronomy. In this inaugural article, he discusses the path that led us to the realization of the true size of the universe and the true insignificance of our own solar system in the grand scheme of things.

Sometimes the most important advances in science come when people realize that a question can be asked. Take a simple question like "Why do the stars shine?" as an example. For most of human history, this was simply a non-issue, a question that was never answered because it was never asked. Stars shone because they were stars, and that was more or less the end of it.

It wasn't until well into the 19th century that scientists looking at stars realized that the fact that we can see them raises fundamental questions. This was at the same time when the branch of physics called thermodynamics — the science of heat and energy — was being developed. For the first time, people realized that the warmth and light we get from the sun isn't free. The energy that pours forth so copiously from our star had to come from somewhere. In 1938 scientists finally realized what the source of the seemingly inexhaustible energy of stars was.

In 1898 an astronomer noted that fossil fish have eyes — an indication that the sun was shining long before human history.

The First Law of Thermodynamics states that energy (including heat) is never created and never destroyed, but simply cycles endlessly from one form to another. Today every scientist uses this unifying principle to make sense of the universe. The first intimation of this law of energy came from a rather unlikely source — a young German student whose academic record can be most charitably described as mediocre and who, at one stage in his career, was arrested and expelled from the University of Tubingen (apparently for activity in a secret society).

Despite all of this, young Julius Mayer took his M.D. and, in 1840, a job as surgeon on a ship bound for the Dutch East Indies. There he made an observation that was to become the basis for a interest that would consume him for the rest of his life.

To understand the observation, you have to remember that this was a time when the medical treatment for most diseases involved bleeding — draining blood from the veins of a patient. Mayer observed that blood from the veins of sailors newly arrived from Europe was redder in color than the blood of those who had been in the tropics for a long time, indicating that there was more oxygen left in the blood of the recent arrivals.

He concluded that it required less oxygen to maintain body temperature in a warmer climate. He argued that the body used less of the "chemical force" in food, and hence used less of the oxygen taken from the air, when the outside temperature was warmer. He realized that the chemical energy of the food was being converted into heat and generalized this insight into the notion that all forms of energy were interchangeable.

Keep Mayer's insight in mind next time you go outside on a sunny day. Turn your face to the sun and feel the warmth. There's energy coming to you, and that energy has been converted to heat from something else. What could that something else be?

Toward the end of the 19th century, astronomers began asking this question. Books from that era often present serious discussions of how long the sun has been shining and what its energy source might be. Writing in 1898, for example, Sir Robert Ball, a Cambridge astronomer, noted that fossil fish have well-developed eyes — an indication that the sun was shining long before human history. He then went on to consider (and dismiss) several rather unusual hypotheses that were floating around at the time. Could the sun just be cooling down from some initial heating during its formation? No, it would long ago have cooled to the point where it no longer emitted visible light. Could it be powered by conventional fuels?

If you start with a lump of anthracite coal (the best fuel known at the time) and assume you could mix in all the oxygen needed to get complete burning, you can calculate how much coal would have to burn each second to produce the observed energy output of the sun and ask how long a lump as big as the sun would last at that rate of consumption. The answer for coal (or petroleum or even pure hydrogen) always turned out to be very short — some 6,000 to 10,000 years. A coal-powered sun wouldn't last much longer than written human history, so clearly the sun wasn't burning ordinary fuels.

What else could do the job? For a while, the leading hypothesis involved gravity. One such theory held that the sun shone because meteorites, comets, and dust were constantly falling into it. Each projectile could bring in energy, the argument went, and could contribute to heating the sun. In essence, the infall would convert the gravitational energy of the meteorites into heat, balancing the energy being emitted in sunlight. Astronomers failed to detect the material that was supposed to be streaming into the sun.

An improved theory, known as the "contraction hypothesis," played a major role in astronomy a century ago and contributed to one of the great controversies of the age. This theory suggested that the source of the gravitational energy that powered the sun was not material falling in from space, but a slow contraction of the sun itself. In this version of the theory, the "fall" of the outer layers of the sun by a small amount would replace the fall of meteorites as the mechanism by which gravitational energy was converted to heat.

The theory was popular for many reasons. For one thing, it didn't require any new or exotic source of energy — everyone at the time was comfortable with gravity. For another, the amount of shrinking needed to keep the sun glowing was too small to be measured directly. The theory was safe from observational contradiction.

It was calculations from this theory that allowed the great British theoretical physicist Lord Kelvin (the man who put the science of thermodynamics into its present form) to estimate the age of the sun and stir up a major scientific debate. A star that is draining its gravitational energy to pay for its radiation can only contract for so long. When Kelvin ran the numbers, he found an age for the sun of between 20 and 100 million years — better than anthracite coal, to be sure, but not nearly enough time to accommodate the data of field geologists and evolutionary theorists. With a peculiar arrogance, Kelvin calmly announced that "the laws of nature" dictated that the disciplines of geology and evolutionary biology were wrong and would have to be redone.

In any case, the contraction hypothesis wasn't long for this world. By the 1920s, our understanding of the working of stars had proceeded to the point that the hypothesis could be tested, if not directly on the sun, then indirectly on other stars. In his monumental book *On the Internal Constitution of Stars*, British astronomer Arthur Eddington codified what was known about the structure of stars and laid the foundation for modern stellar theory. He gave us our current picture in which an intense source of energy located in the stellar core generates a pressure that counteracts the inward pull of gravity, stabilizing the star over a period of many billions of years.

As far as the contraction hypothesis was concerned, he focused on one class of stars, the Cepheid variables, which go through a process of alternate brightening and dimming over a period of weeks or months. For these stars, the length of the cycle depends critically on the radius of the star. Based on the amount of light it was radiating, one such star, Delta Cephei, would require a contraction corresponding to a shortening of the cycle by 17 seconds a year. The star has been observed since 1758, Eddington argued, and such a large change could hardly have been missed. Whatever else you could say about the energy source of Delta Cephei, it clearly wasn't coming from gravity.

Eddington was already famous for having organized the 1919 astronomical expeditions that confirmed Einstein's General Theory of Relativity. (This was the measurement that confirmed the prediction that light rays would bend as they came around the edge of the sun during an eclipse.) Having disposed of the contraction hypothesis, Eddington had to propose something else to power the sun. To understand his suggestion, consider what the scientific world looked like in the 1920s. People knew about Einstein's famous $E = mc^2$ equation, with its implication that mass could be converted into energy. Barely a decade had passed, however, since the discovery that the atom had a nucleus, and the only particles people knew about were the proton and the electron. The discovery of the neutron lay several years in the future. Anyone who wanted to talk about what Eddington called "subatomic energy" in stars had to engage in a good deal of speculation. Nevertheless, it seemed that this new frontier of physics was the only place to look.

Like many of his colleagues, Bethe was forced to flee Germany in the early 1930s after the rise of the Nazis.

Getting more specific, Eddington considered the possibility that what we today call nuclear fusion — the coming together of four protons to form the nucleus of a helium atom — might be the long-sought energy source of stars. The helium nucleus has a slightly smaller mass than the four protons, and the difference between the two is what would be converted into energy according to Einstein's formula. Although Eddington didn't rule this process out, it's clear that he didn't like the idea much, mainly because it limited the lifetime of stars to only some tens of billions of years. (The lifetime of the sun is believed to be about 11 billion years.) His favorite candidate (a process that turns out not to happen in nature) was that electrons and protons would collide and annihilate each other, converting their entire mass into energy and providing a stellar lifetime of thousands of billions of years. Not enough was known about nuclear physics at the time to allow Eddington to give a meaningful quantitative description of how his suggested reactions might work, but he had little time for criticism. "We do not argue with the critic who urges that stars are not hot enough [for nuclear fusion to occur]," he wrote. "We tell him to go find a hotter place."

And this, more or less, is where thinking about the source of stellar energy stalled for a decade. Throughout the rest of the 1920s and most of the 1930s, two parallel lines of research were being carried out. Astronomers were patiently collecting data on stars, working through their bewildering zoology, and reconciling the new data with the general theoretical concepts summarized by Eddington. Nuclear physicists were putting together a detailed picture of the workings of the nucleus. In 1932, British physicist James Chadwick discovered the neutron, and the simple picture of the nucleus as a collection of protons and neutrons was born. During the next few years, physicists split the nucleus of the atom and began unraveling the diverse reactions that occurred when one nucleus encountered another. But through all this, astronomers never talked to physicists and physicists never talked to astronomers.

Then, in March 1938, the Carnegie Institution of Washington convened a small conference in which nuclear physicists and astronomers got together to talk to each other. One of the attendees was a German émigré physicist named Hans Bethe. Years later, in his Nobel Prize lecture, Bethe described the conference like this:

At this conference the astrophysicists told physicists what they knew about the internal constitution of stars. All of their results were derived without knowledge of a specific source of energy. All that was necessary was that most of the energy was produced near the center of the star.

Bethe was a member of a cohort of young German scientists who came to maturity at a time when German universities and German physicists were unquestioned world leaders, when young scientists from all over the world dreamed of traveling to that country to study. Like many of his colleagues, Bethe was forced to flee Germany in the early 1930s, after the rise of Adolf Hitler and the Nazis.

According to physics folklore, Bethe listened to what the astrophysicists had to say at that meeting in Washington and then, on the train back to his home base at Cornell, produced the first fully worked out theory of how nuclear fusion could produce the energy that makes stars shine. It is that train ride that I am proposing as today's Great Moment in Astronomy. The results were published in a monumental paper titled "Energy Production in Stars" in 1939 and eventually led to Bethe's Nobel Prize in 1967.

He took the best information available about nuclear reactions at the time and showed, in detail, how it is possible for four protons to come together to form a helium nucleus, releasing energy as Eddington had suggested. Actually, the process Bethe worked out in that paper — what is known today as the carbon cycle — involves a rather complex chain of six nuclear reactions in which nuclei of carbon and nitrogen act as catalysts for the fusion process. At the time, astronomers estimated that temperatures at the center of the sun were around 19 million degrees Kelvin, and Bethe showed that at that temperature the carbon cycle would be the dominant mode of energy production.

Today, the accepted value of the sun's core temperature is about eight million degrees Kelvin, and at that temperature (as Bethe pointed out in his paper), a completely different set of nuclear reactions — what is called the proton-proton chain — dominates. Today, we believe that the carbon cycle operates only in larger stars. But the point is that in 1939, for the first time, two branches of science came together to explain why stars shine.

Since that fateful train ride, working out the life cycle of stars by melding the theory of stellar structure and knowledge of nuclear reactions has become something of a cottage industry in astronomical circles. Astronomers now speak confidently of the death of our own sun (a comfortable six and a half billion years from now) and the explosions of giant stars in supernovae. If there's one thing everyone knows, it's that it is the conversion of hydrogen to helium that powers the sun and sustains all life on Earth.

But do we really know that? Starting in the 1960s, a series of experiments began that has raised nagging questions about how well we understand the nuclear reactions in our own star. The basic idea behind these experiments is that some of the reactions in the fusion chain produce particles called neutrinos as a kind of by-product. Neutrinos are massless particles with no electrical charge and extremely weak interactions with matter — a neutrino can travel through light years of solid lead without jostling a single atom, for example. Neutrinos produced in the core of the sun will come out into space with hardly any interactions, cross the gulf between the sun and Earth, and, in most cases, pass right through Earth and proceed on their way. Millions of these neutrinos are passing through your body as you read this, but during your lifetime only a few representatives of this flood will actually interact with your atoms. The key point is that the neutrinos carry information about the core of the sun, where the energy is being generated.

We are only seeing between a third and half of the neutrinos we ought to see if the sun's energy is being produced by nuclear fusion.

Ray Davis of Brookhaven National Laboratory set out to detect these neutrinos by setting up a tank of cleaning fluid the size of a railroad car in a gold mine a mile underground in Lead, South Dakota. He predicted that the solar neutrinos passing through would occasionally interact with a chlorine nucleus in the fluid, changing it into argon. Periodically, the number of atoms of argon in the tank would be measured and from this the flux of neutrinos would be determined.

When this experiment first went on line, almost no neutrinos were detected. According to the best theoretical estimates of the time, there should have been hundreds of events per day, and this meant either our understanding of the sun wasn't as complete as we thought or there was something seriously wrong with the experiment itself. The discrepancy between the theoretical prediction and the experimental result became known as the "solar neutrino problem."

Over the years, scientists worked hard to close the loopholes in their predictions of the number of neutrinos that ought to be detected in Davis's apparatus. A reaction rate was measured a little more accurately here, the computer model of the sun's interior was tweaked a little there, and (of course) the experiment itself was put through rigorous tests. Today, several more neutrino detectors are operating around the world. The verdict from all of them is the same — we are seeing between a third and half of the neutrinos we ought to see if the sun's energy is being produced by nuclear fusion.

At the moment, the explanation for this phenomenon involves the properties of the neutrinos themselves, rather than properties of the sun. In essence, scientists suggest that between the time they are generated in the sun and the time they reach their earthly targets, some neutrinos undergo reactions that change their identities, making it impossible for them to affect nuclei in the experimental apparatus. If this property of neutrinos is verified independently in laboratory experiments, then we can all breathe a sigh of relief and relax, secure in the knowledge that we really do understand the energy production in stars. If it isn't, however, it may be back to the drawing board on this whole issue.

Anyone want to place a bet on anthracite coal? ▣

Physicist James Trefil is a member of Astronomy's *editorial advisory board.*

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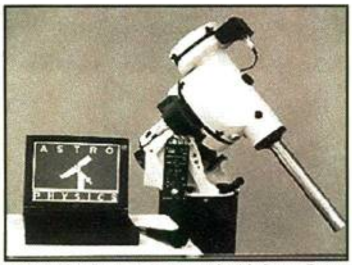

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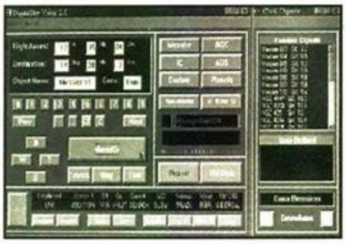

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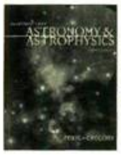

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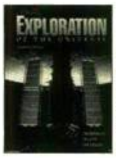

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THE SKY SHOW

Lovely Luna creates a striking trio with Venus and Mars twice this month, appears in very close conjunction with Jupiter, and embraces Saturn — all in an attempt to entice observers out under the chilly winter skies. By Martin Ratcliffe and Alister Ling

▶ Planetary conjunctions are a familiar sight to astronomers keeping a careful watch on the skies, and late this month one of the finest conjunctions occurs. Though a full 342 million miles apart, **Mars** and **Jupiter** will lie along the same line of sight as seen by observers on Earth during January. By January 20, shortly after sunset, the pair of planets will be less than half the moon's width, or 11', apart. This pairing takes place in Capricornus the Sea Goat, although the constellation's faint stars will be hard to see due to the twilight glow of the evening sunset. Jupiter will be easier to see, shining at a brilliant magnitude –2.0. Jupiter is falling toward a late February rendezvous with the sun, also called a conjunction, and will pass into the morning sky. Mars, fainter at magnitude 1.2, will continue to linger in the evening twilight for a couple of months. Not until May does the Red Planet pass behind the sun, its first solar conjunction in two years.

Adding to this New Year spectacle is a slim crescent moon, which passes a scant 3° north of Jupiter on January 1. A lunar month later the moon is found 2° north of Jupiter and Mars, on January 29. Also in early January look out for the 2.8-magnitude star, Delta (δ) Capricorni, southeast of Jupiter. On this first evening of 1998, Mars and **Venus** are strung out along a line that leads toward the already set sun. Venus outshines Jupiter by 2.5 magnitudes and appears as a brilliant –4.6-magnitude "star" low in the southwest shortly after sunset. Mars lies roughly midway between Venus and Jupiter. Watch during the following three weeks as Venus slips away into the sun's glow and Mars and Jupiter draw close for their midmonth encounter. Venus reaches inferior

Cold winter evenings offer crisp skies and beautiful sunsets. Take advantage of these conditions to enjoy January's planetary encounters with the moon, such as the one below with Venus.

Randall Wehler

JANUARY 1998

1 The moon passes 3° north of Jupiter, 6 p.m. EST

3 The moon is at perigee (229,435 miles from Earth), 3:32 a.m. EST
Quadrantid meteor shower peaks (page 68)

4 Earth is at perihelion (91.4 million miles from the sun), 4 p.m. EST

5 The moon passes 0.2° south of Saturn, 7 a.m. EST
First quarter moon is at 9:18 a.m. EST

6 Mercury is at greatest western elongation (23°), 10 a.m. EST

7 Mars is at perihelion (128.4 million miles from the sun), 6 a.m. EST

9 The moon passes 0.4° north of Aldebaran, 8 a.m. EST
Venus passes 4° north of Neptune, noon EST

12 Full moon is at 12:24 p.m. EST

16 Venus is in inferior conjunction, 6 a.m. EST (page 69)

18 The moon is at apogee (251,429 miles from Earth), 3:40 p.m. EST

19 Neptune is in conjunction with the sun, 6 p.m. EST

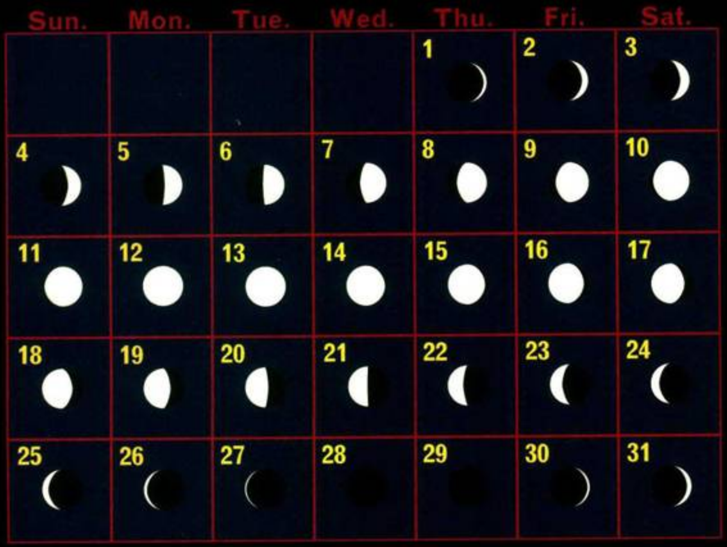
20 Last quarter moon is at 2:40 p.m. EST
Mars passes 0.2° south of Jupiter, 8 p.m. EST

26 Mercury passes 8° south of Venus, noon EST
The moon passes 3° south of Venus, 7 p.m. EST
The moon passes 5° north of Mercury, 8 p.m. EST

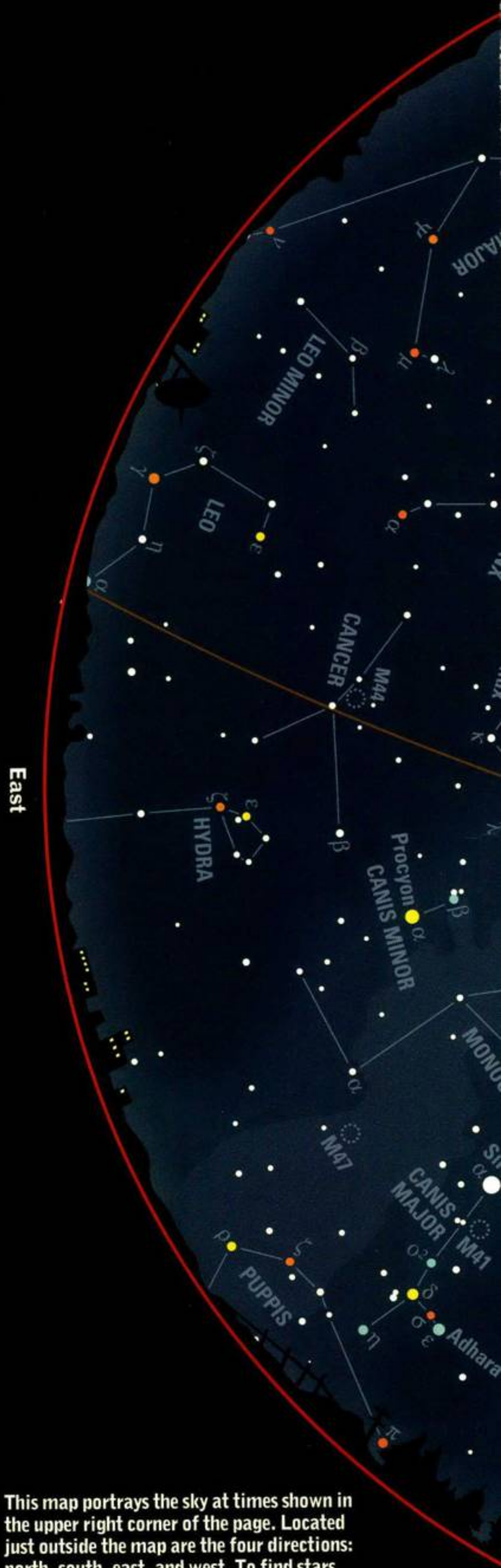
28 New moon is at 1:01 a.m. EST
Uranus is in conjunction with the sun, 3 p.m. EST

29 The moon passes 2° north of Jupiter, noon EST
The moon passes 1.7° north of Mars, 8 p.m. EST

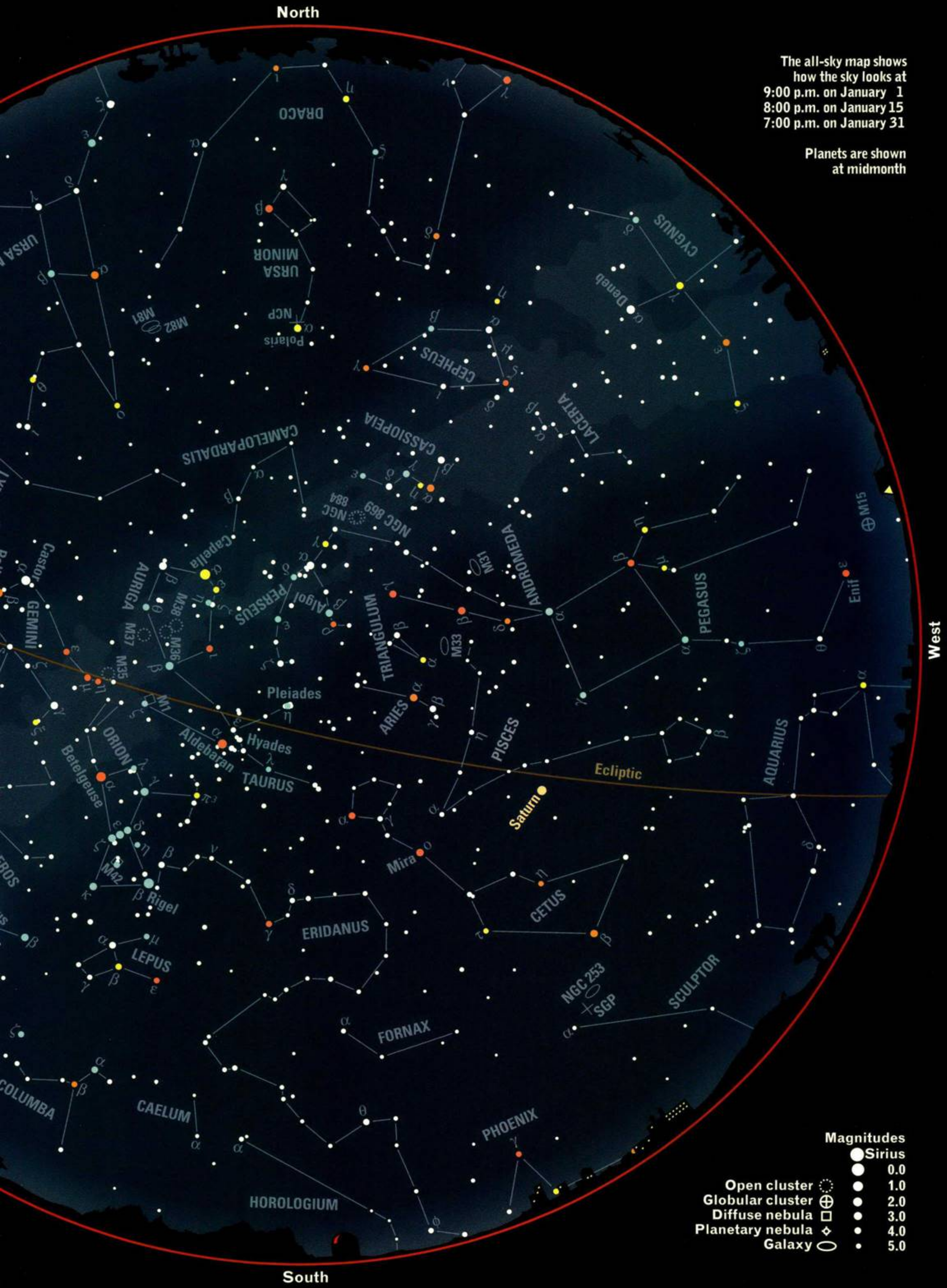
30 The moon is at perigee (226,055 miles from Earth), 9:11 a.m. EST



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31



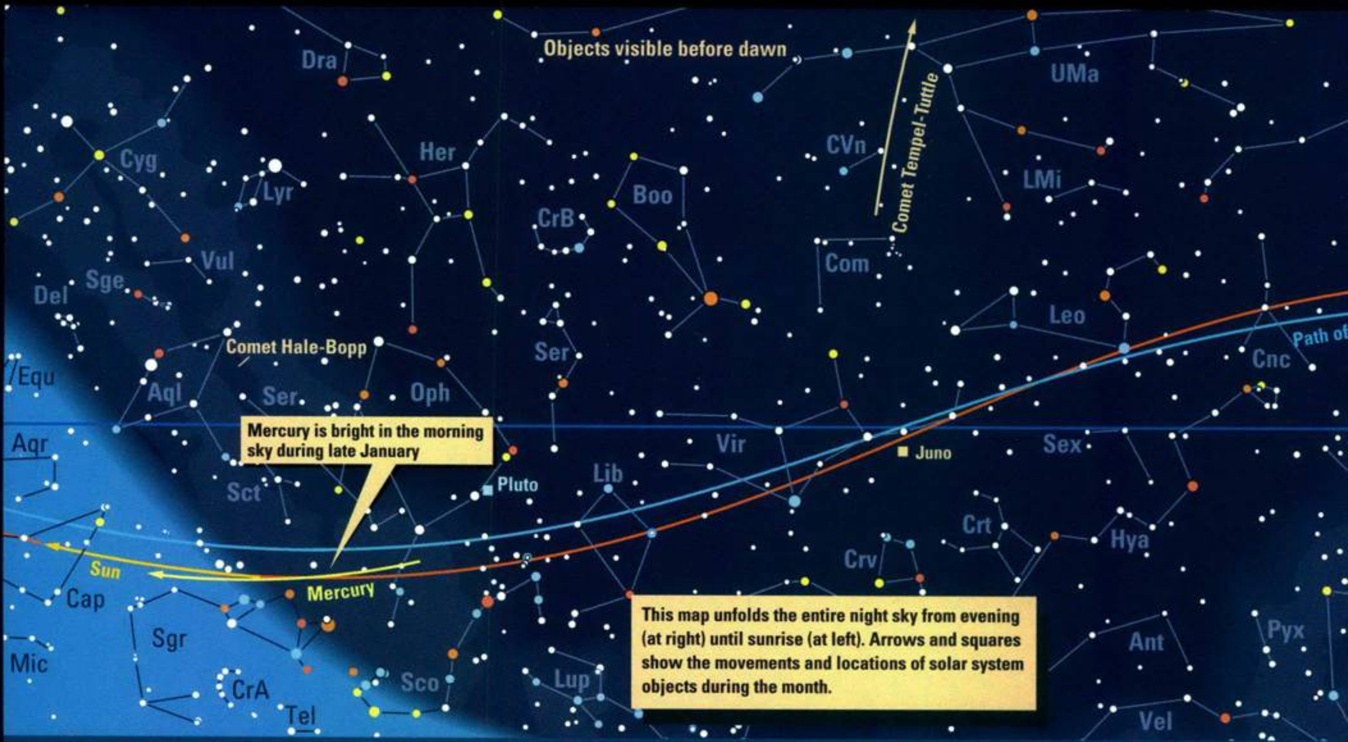
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


North
West
South
DRACO
URSA MINOR
URSA
NCP
Polaris
M81
M82
CEPHEUS
CYGNUS
Deneb
LACERTA
CASSIOPEIA
CAMELOPARDALIS
NGC 869
NGC 884
Capella
AURIGA
PERSEUS
Algol
M37
M38
M36
M35
Castor
GEMINI
ANDROMEDA
M31
M33
TRIANGULUM
PEGASUS
Enif
M15
Pleiades
Hyades
Aldebaran
TAURUS
M1
ORION
Betelgeuse
Rigel
M42
ARIES
PISCES
AQUARIUS
Ecliptic
Saturn
Mira
CETUS
ERIDANUS
LEPUS
FORNAX
NGC 253
SGP
SCULPTOR
PHOENIX
COLUMBA
CAELUM
HOROLOGIUM
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
9:00 p.m. on January 1
8:00 p.m. on January 15
7:00 p.m. on January 31

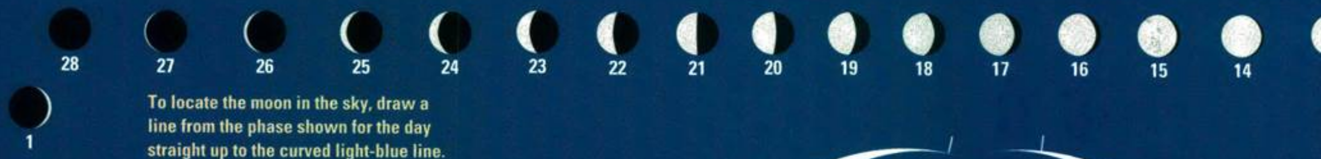
Planets are shown
at midmonth

THE PATH OF THE PLANETS


Objects visible before dawn
Dra
Cyg
Lyr
Her
CrB
Boo
CVn
Comet Tempel-Tuttle
UMa
LMi
Vul
Sge
Del
Com
Leo
Comet Hale-Bopp
Ser
Equ
Aql
Ser
Oph
Cnc
Path of
Aqr
Vir
Juno
Sex
Sct
Pluto
Lib
Crt
Hya
Sun
Crv
Cap
Mercury
Sgr
Ant
Pyx
Mic
CrA
Sco
Lup
Tel
Vel

Mercury is bright in the morning sky during late January

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.


28
27
26
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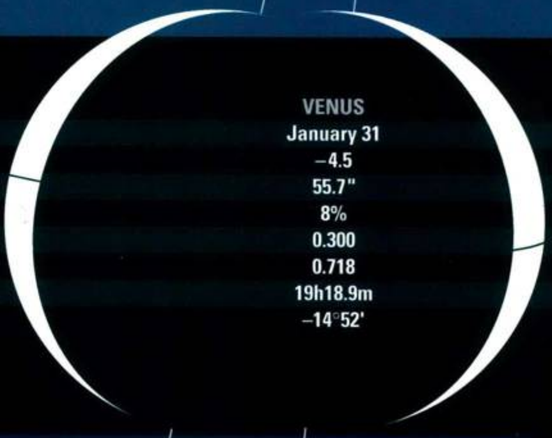
14
1

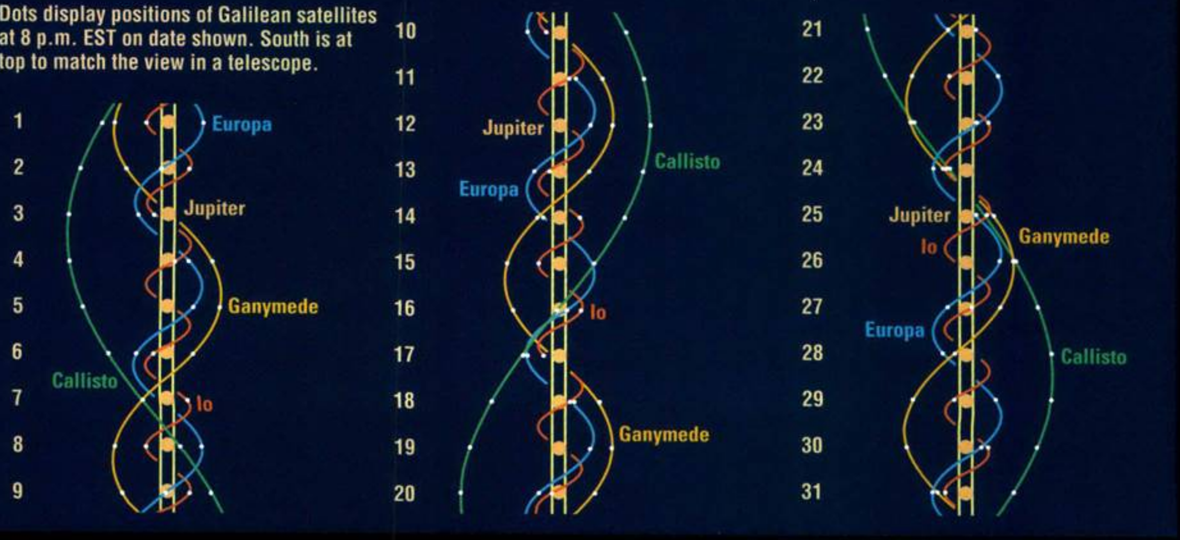
To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

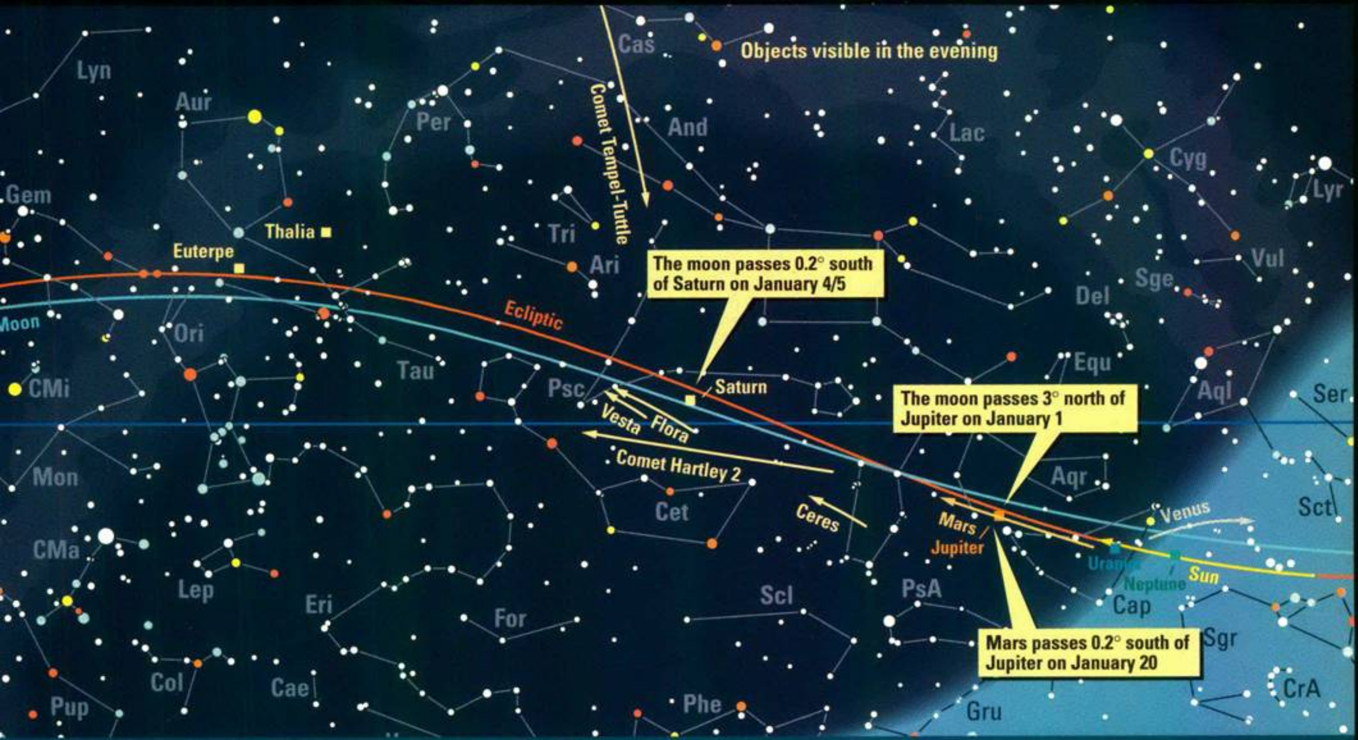


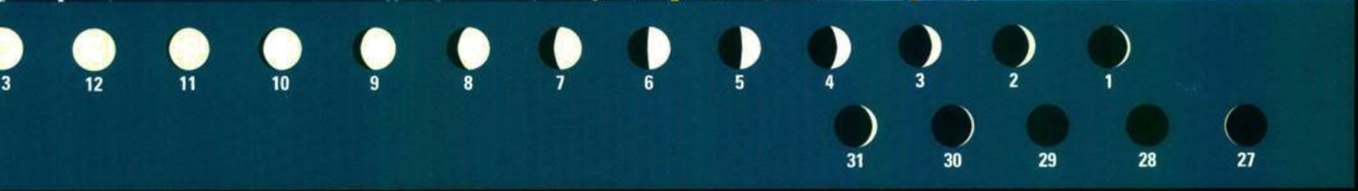
PLANETS	MERCURY	MERCURY	VENUS	VENUS	MAR
Date	January 1	January 31	January 1	January 31	Januar
Magnitude	−0.1	−0.4	−4.5	−4.5	1.2
Angular Size	7.5"	5.0"	56.2"	55.7"	4.3"
Illumination	48%	92%	8%	8%	97%
Distance (AU) from Earth	0.899	1.341	0.297	0.300	2.18
Distance (AU) from Sun	0.369	0.466	0.720	0.718	1.38
Right Ascension (2000.0)	17h11.0m	19h52.8m	20h21.0m	19h18.9m	21h38.
Declination (2000.0)	−20°25'	−22°19'	−17°24'	−14°52'	−15°1

JUPITER'S MOONS

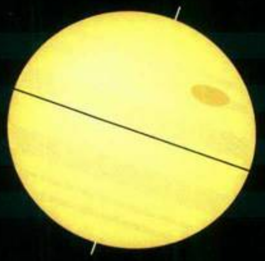
Dots display positions of Galilean satellites at 8 p.m. EST on date shown. South is at top to match the view in a telescope.

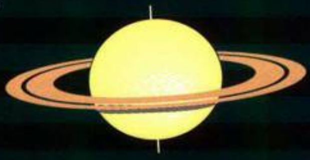



Objects visible in the evening
Cas
Lyn
Aur
Per
Comet Tempel-Tuttle
And
Lac
Cyg
Lyr
Gem
Thalia
Euterpe
Tri
Ari
The moon passes 0.2° south of Saturn on January 4/5
Vul
Sge
Del
Moon
Ecliptic
Ori
Tau
Equ
CMi
Psc
Saturn
Vesta
Flora
The moon passes 3° north of Jupiter on January 1
Aql
Ser
Comet Hartley 2
Mon
Aqr
Ceres
Cet
Mars / Jupiter
Venus
Sct
CMa
Uranus
Neptune
Sun
Lep
Eri
Scl
PsA
Cap
For
Mars passes 0.2° south of Jupiter on January 20
Sgr
Col
Cae
Phe
Gru
CrA
Pup

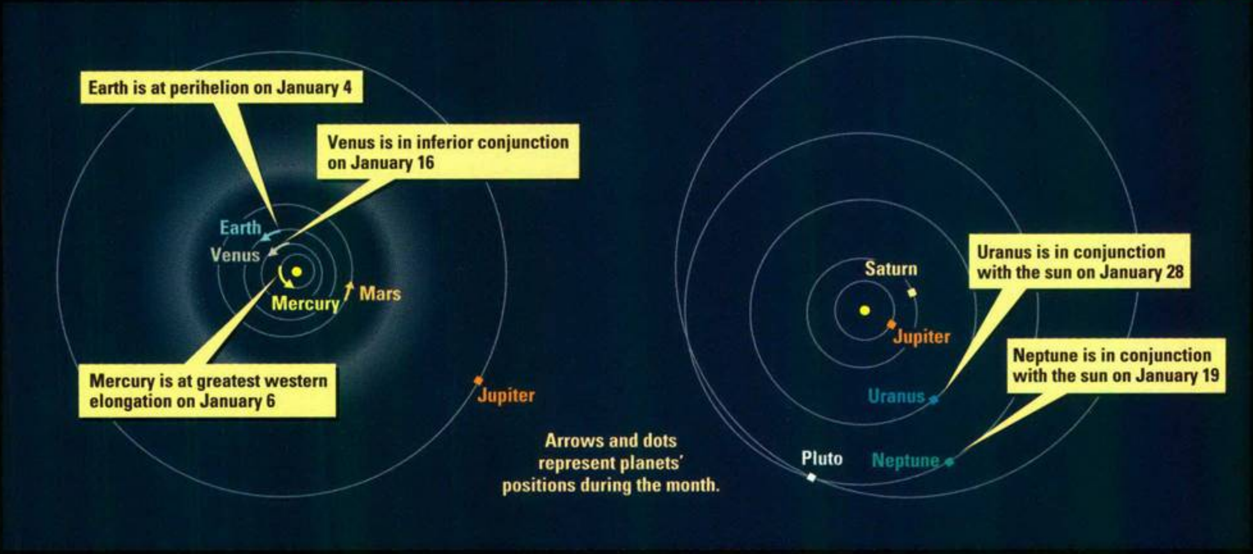

3
12
11
10
9
8
7
6
5
4
3
2
1
31
30
29
28
27

	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
15	January 15	January 15	January 15	January 15	January 15
	−2.0	0.7	5.9	8.0	13.8
	33.8"	17.5"	3.4"	2.2"	0.1"
	100%	100%	100%	100%	100%
	5.838	9.488	20.802	31.125	30.675
	5.017	9.363	19.846	30.145	30.033
m	21h51.5m	0h56.7m	20h42.0m	20h06.3m	16h29.7m
'	−13°54'	3°24'	−18°52'	−19°54'	−9°44'





THE PLANETS IN THEIR ORBITS

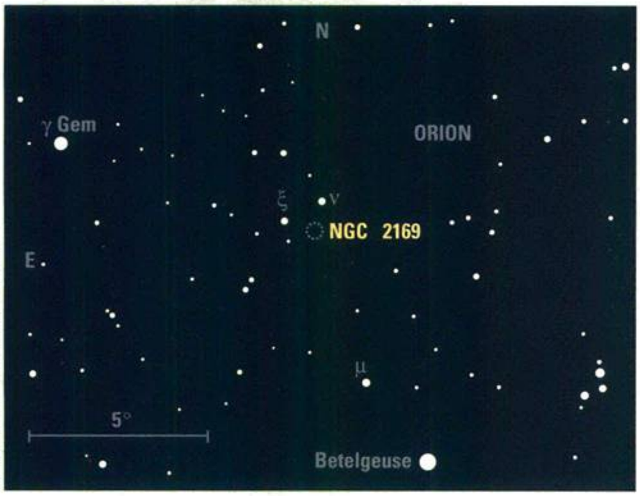

Earth is at perihelion on January 4
Venus is in inferior conjunction on January 16
Earth
Venus
Mercury
Mars
Mercury is at greatest western elongation on January 6
Jupiter
Saturn
Jupiter
Uranus is in conjunction with the sun on January 28
Neptune is in conjunction with the sun on January 19
Uranus
Pluto
Neptune

Arrows and dots represent planets' positions during the month.

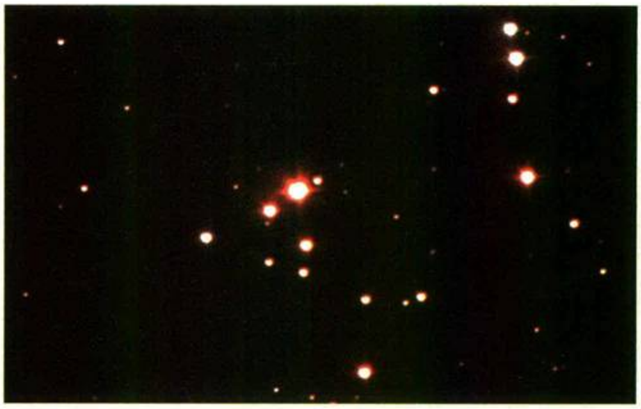
FIRST VIEWS: The "37" Cluster

Our imagination is fired by deep-sky objects that resemble earthly counterparts — the Lagoon Nebula, the Veil Nebula, and so on. But have you ever seen one that looks like a number? You should check out the "37." This star cluster ought to be better known than it is — it is so bright and easy to spot that a small scope will display its number through the toughest city glare.

Tucked away as a bump on Orion's raised club, NGC 2169 is a compact group of 15 to 30 stars, incredibly arranged into two angular strings, unmistakably in the shape of numbers.



All illustrations by *Astronomy*: Terri Field



Tim Puckett

The brightest member is a 7th-magnitude luminary in the "top left" of the "3." Owners of SCTs and refractors who use star diagonals will get the numbers flipped left to right, making the "3" look like the Greek capital letter Sigma. But even users of Newtonian reflectors will have to twist their heads to see "37" the right way up.

Next to the brightest star is an Otto Struve double. S848 is a pair consisting of 8.3- and 9.0-magnitude stars separated by 2.5", a comfortable split in any small telescope at high power. The "37" can be found at 6h8.4m 13°57' (2000), not quite halfway from Betelgeuse to the more famous M35. Once you remember how to find NGC 2169, the "37" is sure to become a fixed favorite in the winter sky.

conjunction on January 16 and passes into the morning sky. Look again to the morning sky to watch a waning crescent moon slip just 3° south of Venus on January 26.

The combined motions of the planets naturally bring them closer together from time to time. Regular readers will remember that **Uranus** and **Neptune** are within the same region of Capricornus as Mars and Jupiter. In fact, on January 15, Venus, Mars, Jupiter, Uranus, Neptune, and the sun all lie within a 30° circle. Such alignments (there's another one on May 5, 2000) often bring the soothsayers and doom-mongers out of the closet to try to convince the unwitting and gullible that the end of the world is nigh. Earth dwellers have often seen these events and lived through them unscathed, but facts don't seem to halt the fortune-tellers of the world. The facts are that this is yet another planetary alignment, but not a particularly close one, and the variety of events on Earth will be as good or bad as they usually are.

Two planets, Uranus and Neptune, pass on the far side of the sun as seen from Earth this month. Neptune reaches conjunction with the sun on January 19 and Uranus reaches its conjunction with the sun on January 28.

Soon after dusk the flurry of planetary activity settles, and **Saturn** is left as the dominant planet in the night sky, moving along grandly among the dim stars of Pisces. Saturn shines at magnitude 0.7 and lies to the south of Delta (δ) Piscium, a 4th-magnitude star in the southern half of the constellation. An almost first quarter moon lies to the west of Saturn on January 4 and has moved to the east of the planet by the following evening. Saturn's remarkable rings can be viewed in any small scope; if you don't own one, ask a friend or neighbor to show you Saturn.

A little more difficult to track down than Saturn is the return of Comet Tempel-Tuttle, the parent comet to the Leonid meteor shower. It reaches perihelion next month but is at its brightest during January, glowing at around 9th magnitude. This small fuzzball should just be visible in binoculars and small telescopes and will appear like a small, roundish, dim, misty patch of light. On the nights of January 15 and 16, Comet Tempel-Tuttle lies within 7° of Polaris, the Pole Star. The comet is closest to Earth on January 17. Moving swiftly from night to night, Tempel-Tuttle passes close to Epsilon (ε) Cassiopeiae on January 20 as the comet dives toward the ecliptic plane.

The chief interest in this comet is its association with the Leonid meteor shower which occurs in November of every year. Roughly every 33 years, around the time of the parent comet's return to the inner solar system, the shower turns into a meteor storm for a brief time. This last occurred in November 1966 and is next expected to occur in 1998 or 1999. We'll have to wait until November to find out if the meteor show will take place this year or next.

Any meteors seen this month are not associated with Comet Tempel-Tuttle, but rather Comet Machholz, discovered in 1986. Machholz produces the annual Quadrantid meteor shower of up to 100 meteors per hour, the result of cometary debris left in the comet's wake and through which Earth passes around January 4. The radiant for the shower, the point in space from which the meteors appear to radiate, lies in the region of sky bounded by northern Bootes, Draco, and the handle of the Big Dipper. This area used to house the now obsolete constellation Quadrans Muralis.

The winter sky is dominated by the splendid shape of Orion the Hunter. Its seven bright stars, from Betelgeuse at the top left of the group down to Rigel in the bottom right, punctuate the black sky like no other group. These bright stars make it easy to discern the outline of the mythological figure the constellation represents. Betelgeuse is usually translated as "armpit of the giant" or the "arm/shoulder of the great one." The star Rigel is translated as the "left leg of the giant," while the three stars of Orion's belt — Mintaka, Alnilam, and Alnitak — all refer to a belt or girdle.

The upper of the three stars of Orion's Belt, Mintaka, lies a fraction below the imaginary celestial equator. This line can be found directly above Earth's equator and splits the sky into two convenient hemispheres.

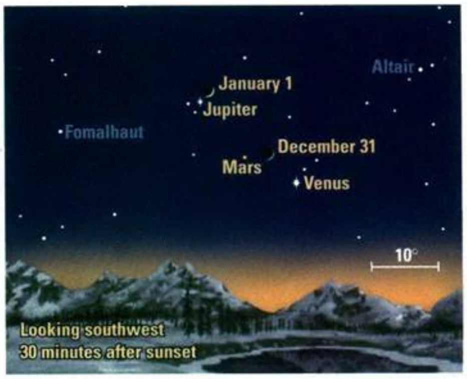
Splendid Line-Up for the New Year

Make sure your binoculars, camera, and winter gear are ready and waiting to go — this month features some of the best planetary line-ups the evening sky can ever offer.

Take note that we start the evening alignment in late December. On the 30th, a young crescent moon (just 29 hours old) graces the orange twilight. By New Year's Eve, the moon creates a striking trio with dazzling Venus and reddish Mars — make sure you strongly encourage your co-workers, friends, and relatives to look outside at the "very early" hour of 5 p.m.

The following night's extremely close conjunction of the crescent moon and Jupiter may lead the superstitious to think that the sky is offering an evil omen. Others will just sit back and enjoy the splendid sight. The moon and planet come within two degrees of one another — a perfect binocular treat.

Saturn joins in the fray on the evenings of the 4th and 5th as the moon straddles each side of its steady yellow glow.



Keep an eye on Mars and Jupiter — each night they close in on one another. They're within binocular range on the 10th, but the best is yet to come. Mars skims a mere 11' past Jupiter and its moons on the 20th.

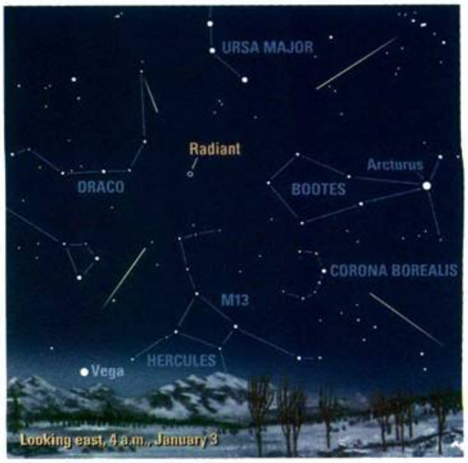
While you're watching Mars and Jupiter separate each evening thereafter, remember that the moon is about to come around for another crescent encounter with the pair. On the 29th it will lie right between them.

Questionable Quadrantids

Gert Kroner

The Quadrantid shower is well known to meteor observers. It has a sharp and productive peak of activity, but within a handful of hours, the rate plummets. Quadrantids don't belong to a constellation the way the Geminids or Perseids do because the old constellation Quadrans Muralis was discarded a century ago — instead, the Muralis stars were joined to Bootes. On a dark night, when the meteors stream from high in the sky, observers have noted up to 150 per hour. Unfortunately, the peak of the shower is forecast to arrive at noon EST on the 3rd. If the arrival is early, those on the east coast will still have to battle the light of the crescent moon, almost five days after its new phase.

Perhaps the best location for viewing the Quadrantids is from a hot tub. That way, if the shower doesn't pull through, you'll still have had an enjoyable night.



Another important line across the sky is the ecliptic. This can be understood in two ways — first as the projection of Earth's orbit on the sky. It is inclined 23.5° to the celestial equator. Alternatively, the Ptolemaic view of the ecliptic is that it represents the path of the sun throughout the year relative to the starry background. This apparent motion of the sun, of course, is caused by Earth's orbital motion around the sun.

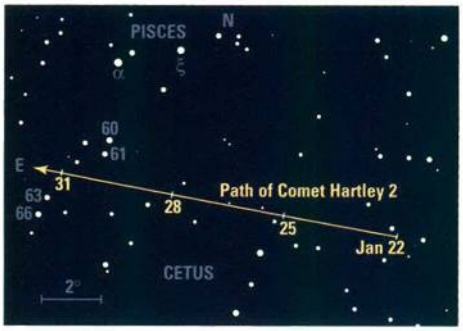
Neighboring Orion, lying along the ecliptic, is Taurus the Bull, one of the oldest constellations. To find Taurus, use the three bright stars of Orion's belt as a guide. Aldebaran, a red giant star almost 40 times larger than the sun, can be found by extending a line upwards from the line of stars in Orion's belt. Taurus does not contain many bright stars but houses a distinctive V-shape of stars called the Hyades; one tip of this V is accented by brilliant Aldebaran.

Aside from Aldebaran, this group of stars is united in space, traveling together as one true open cluster. The Hyades lie almost 140 light-years from Earth, while Aldebaran is less than half that distance, at 68 light-years. By comparison, Zeta (ζ) Tauri, representing one of the horns of the Bull, lies almost 1,000 light-years away.

It is close to Zeta that the first Messier object resides. Messier objects are the 103 brightest nebulae, galaxies, and star clusters as catalogued in 1784 by French astronomer Charles Messier. M1, also known as the Crab Nebula, is unique in other respects too. This remarkable object is the shattered remains of a star that blew itself to pieces in 1054 A.D.

Periodic Comet Hartley 2 Near Its Best

Barring a surprise visitor to the solar system, P/Hartley 2 will be the comet of choice to watch this month. After its December 21 close approach to the sun — perihelion — this celestial snowball should be shining at around 8th magnitude. Most of our encounters with this short-period comet (every 6.4 years) don't generate much news because the Earth-sun-comet geometry is so poor. This time, however, our position is more advantageous. Although you might be able to pick up P/Hartley 2 from a suburban backyard with a mid-sized scope, it's best to head out to dark skies and wait until after midmonth so that the moon will be out of sight. Be sure to try a wide range of magnifications. Low power will show you the greatest extent of the short fan-shaped tail. Higher power reveals hidden detail in the inner coma and possibly the tail.

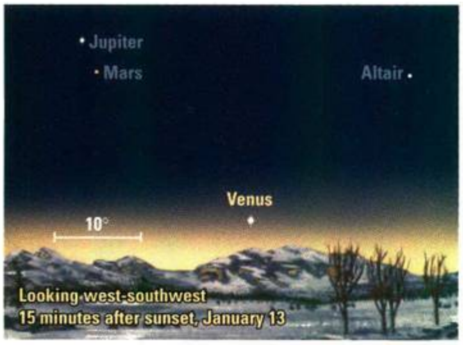


Venus Is Superior When It's Inferior

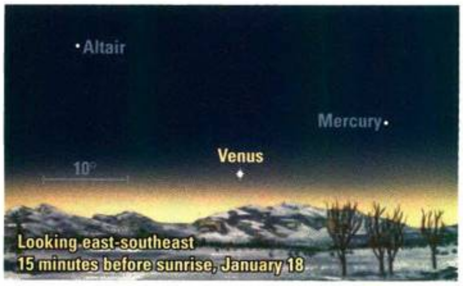
The blazing planet Venus is both an evening and morning star this month because it swings quickly between the sun and Earth in its orbit — inferior conjunction occurs when all three line up. Venus easily tops the other planets in its action. It grows to a remarkable 60" across (Jupiter is only 40" across). Within a couple of days of the 15th, if you're a brave soul who is extremely careful, you may see the cusps of Venus's crescent grow to encircle the planet. Start by offsetting your covered scope (and finder scope) six degrees north of the sun, and then remove the finder and objective caps. Do not try this unless you have guidance from an experienced observer or can take all the necessary precautions to prevent accidental eye injury.

If you're not up for dangerous daylight sport, test your twilight binocular skills to see if you can notice Venus's four-day disappearing act. You might still be able to see it on the 13th, but then it will vanish until the 18th, when it will reappear low in the morning twilight.

And as if it hadn't already done enough to impress you, Venus will scoot past Mercury in the morning twilight of the 26th. Spotting Mercury will be tough, but use the crescent moon to guide you one full binocular field (7°) straight down into the murk hugging the horizon.



Looking west-southwest
15 minutes after sunset, January 13



Looking east-southeast
15 minutes before sunrise, January 18

Mark Payne-Gill

OBSERVER'S CHALLENGE: Abell 12 — A Blooming Planetary

Finally, here's an object that may be easier for observers to see than for photographers to catch on film or even with a CCD. This large planetary nebula is so close to 4.4-magnitude Mu (μ) Orionis that the star's light bleeds or blooms across an image and hides the adjacent nebula.

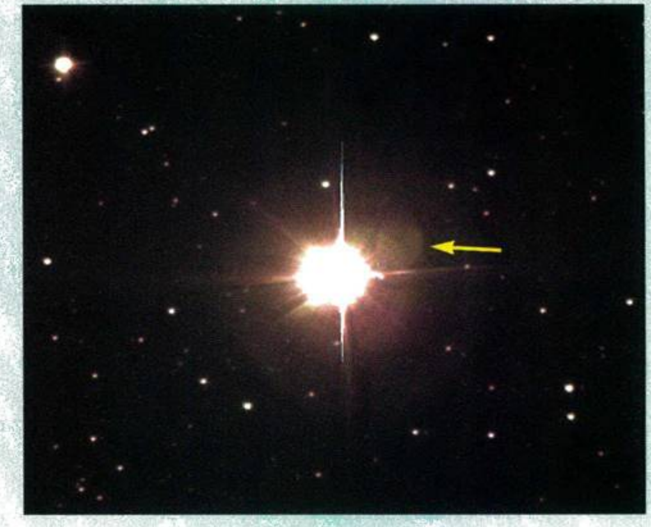
Eagle-eyed George Abell discovered this planetary, which spans 37" — about half the size of the well known Ring Nebula — while scanning the Palomar Observatory Sky Survey not far from Betelgeuse. How he saw it is a mystery to me; even knowing where to look on the prints, I couldn't make it out in the glare of Mu Orionis, just 1' away.

Visual observation is another matter. The great news is that at 12th magnitude, Abell 12 can easily be picked up in a 12-inch scope with a nebular filter, west and a little north of Mu Orionis. Armed with an O III filter and a drive to keep Mu out of the field, observers have sighted Abell 12 in scopes as small as seven inches across.

Another trick is to take an old eyepiece like an Orthoscopic and place a rectangular bar of aluminum foil at the field stop in the barrel of the eyepiece. This way a sharply focused dark bar cuts across the view, and you can hide Mu behind the bar to kill the glare. While a drive is not necessary, it sure makes things easier.

George Abell discovered just over 80 of these large but faint planetary nebulae while scouting the Palomar Sky Survey. They are easier to find than you might think. A narrow band filter is a minimum requirement — without this small accessory the visual hunters of the 19th century were unable to detect Abell nebulae.

Abell planetaries are plotted in atlases like *Uranometria* and software like *Guide*. Use their common name index to search for the Abell name directly. Don't let the published magnitude scare you off — frequently it's much fainter than what we see visually. Abell 2 and 82 in Cassiopeia are examples of planetaries readily visible in a 12.5-inch scope.


Tim Puckett

Start off at low power using an O III filter if you have one, and make sure you take precautions to shade your eyes or observe under a dark hood. Stray light bounces off the shiny filter and reduces contrast in the eyepiece. In the case of Abell 82, you're looking for a ghostly puffball bigger than the Ring Nebula, whereas Abell 2 is about half M57's size.

I like the idea of an observing project to nab all the Abell planetaries — it is a relaxing challenge that can be achieved within a couple of years. Apart from skipping a couple of nonexistent objects and a handful of extremely faint ones, you can experience a lot of satisfaction in completing this catalog.

Let *Astronomy* know how you did with this and other observing challenges.

and was recorded by Chinese and Japanese observers. Today the expanding cloud of debris can be viewed with medium-sized scopes (6-inch diameter or larger). Center Zeta Tauri in your scope and scan about a degree to the northwest to find the dim glow from the Crab Nebula.

Since the moon also traverses the ecliptic region every month, it passes in front of many stars along the ecliptic or within the zodiacal constellations. In fact, it was an occultation of the Crab Nebula by the moon that gave one of the early confirmations that the radio source and the visible nebula were associated. Since then the rapidly rotating pulsar in the center of the Crab has been well documented, most recently by the Hubble Space Telescope.

Early in the morning of January 9, the moon occults some of the stars in the Hyades. This is one of the best events to observe if you are new to observing these events; so many occultations happen over a short time interval that you can use the multiple events to hone your observing skills.

High above Taurus and passing overhead in the early evening is Perseus. In mythology, Perseus is best known for having killed Medusa, the Gorgon. Her severed head, represented by a circle of stars containing the eclipsing variable star Algol, is in his right hand. Throughout history, Algol has been associated with evil. Its name means "demon star" and "blinking demon." The Chinese dubbed it "a pile of corpses," while the Hebrews knew it as "satan's head." These names are believed to reflect Algol's variable nature.

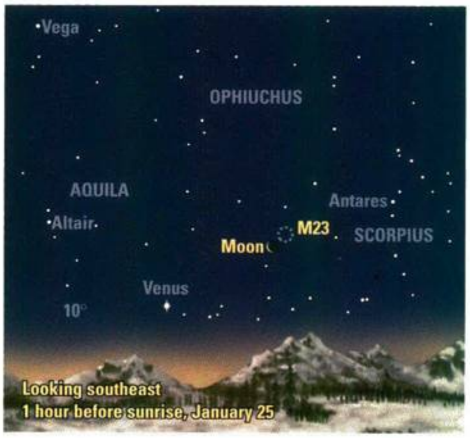
Trailing behind to the east of Perseus is another bright star, Capella in Auriga the Charioteer. Capella is often called the "goat star" because it represents the head of the goat the charioteer holds in his arms. It is the northernmost 1st-magnitude star and, from the latitude of the United States, is visible at some time during any clear night.

Old Moon Does Old Tricks

The planets aren't the only ones worth watching this month. The moon uncovers a star cluster and heads for an ultra sliver at month's end.

On the morning of the 25th, before Venus rises, the star cluster M23 pops back into sight along the moon's dark northern border. The farther east you are, the more action you'll see. Scores of 9th- to 11th-magnitude stars will jump into view as the moon moves eastward.

Use upwards of 150x to catch most of the fainter stars as they reappear. A drive will really be handy to keep the bright limb of the moon out of the field. If you're lucky, there will be enough earthshine to outline the dark limb against the background sky. Unfortunately for those west of a line from Chicago to Dallas, M23 has reappeared by the time the moon rises.



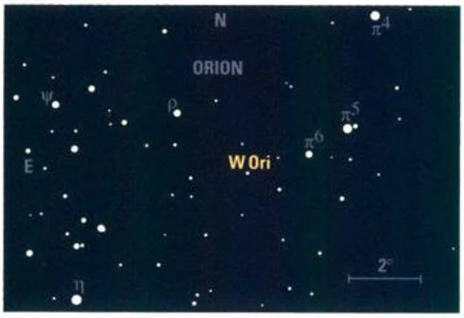
Looking southeast
1 hour before sunrise, January 25

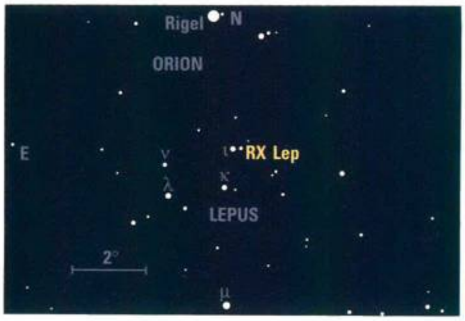
Many of us have seen very young moons — how about a chance to see a very old moon? On the morning of the 27th, folks on the east coast may see one only 19 hours before it's reborn as new. You'll need an excellent horizon with a clean atmosphere to observe this super-thin crescent. Start just after 6:30 a.m. EST.

Two Easy Binocular Variables

Winter skies sport a number of fine variables in a range of classes — my favorites are the binocular-accessible semi-regular variables. These reddish stars pulse without the clockwork cycles of their brethren, so it's always a surprise to see them.

W Orionis is fairly easy to find — add another star to the bottom of Orion's curving shield of pi stars. It ranges from magnitude 5.9 to 6.7, though it can drop to 7.7. RX Leporis has a slightly greater range, from 5.4 to 7.4. It can be found half a binocular field south of Rigel, with RX representing the tip of an inverted golf club or, more appropriately for this season, a hockey stick. Both variables are quite red, and if you stare at them, they get brighter than their neighboring stars — a phenomenon called the Purkinje effect. You can also alternate closing your right and left eyes to see if you have a difference in color perception. Even if you don't take rigorous estimates every two weeks as part of a variable star program with the AAVSO, it's simply neat to observe orangy-red stars change brightness and wonder about them.





Their colors may seem familiar. You've seen them every time you've stared into a fire. They are the hues of glowing carbon, and in this case are the result of starfire.

Farther east are two more 1st-magnitude stars, the pair Castor and Pollux, in Gemini the Twins. Gemini reaches its highest point in the south by midnight during January. By this late hour, Leo is well up above the eastern horizon. Look for the backward questionmark that denotes the lion's head and main. There you'll find the star Regulus, which denotes the heart of the lion. This star has been associated with royalty and kingly power in many ancient civilizations.

As the night progresses and dawn approaches, the spring constellations make a reappearance. Arcturus in Bootes the Herdsman is the first bright spring star to poke its head above the eastern horizon. Through the cold early morning hours of winter, Arcturus rises high above the southern horizon, while Antares begins to peak through the first glows of the returning sun. On January 6, take some time to look for elusive **Mercury**. The planet will be making a brief morning appearance to the east of Antares. On this date, Mercury reaches its greatest western elongation (23°) and will be visible about 6:30 a.m. before the sky begins to brighten and drown out its feeble glow. By the end of the month, Mercury will disappear chasing the sun for a conjunction next month, and Venus will appear from its conjunction in the morning before dawn.

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

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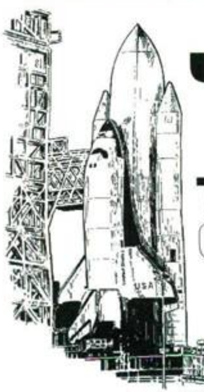

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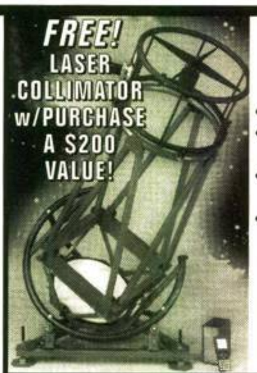

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TURNING FAMILIAR *into*

Been there, done that? Here's how you can enliven familiar sky favorites.

(left) Christian Viladrich; (right) Lick Observatory

Humans, let's face it, are prisoners of habit. We get together with old friends and return to familiar, favorite restaurant where we order our usual entrées. No wonder we point telescopes toward the same handful of objects time and again. Our visitors may marvel that we can locate Saturn in the confusing, twinkling quilt of the heavens; they don't know that we've already performed this trick a hundred times this winter. The skill we're really demonstrating is our mastery of inertia.

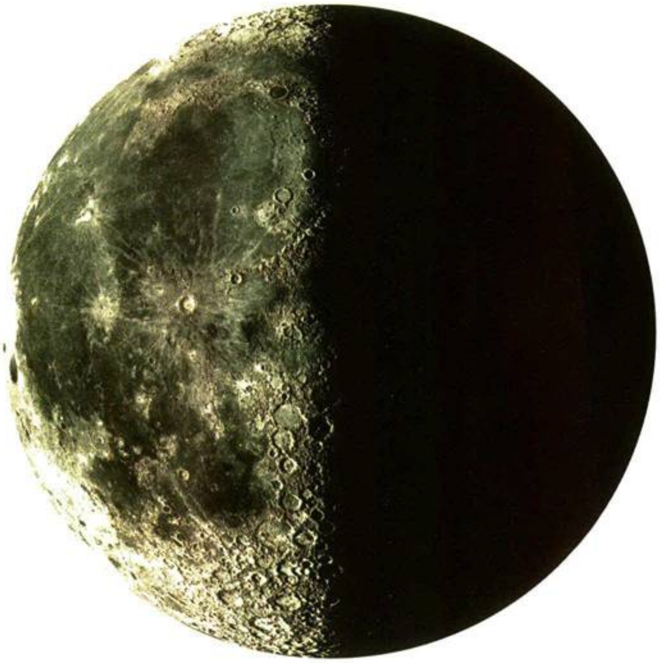
You probably think I'm going to suggest new telescope targets. No way. There are enough excellent articles about that in this magazine, and few of them convince you to budge from your habits. The real problem is that it's simply easier to return to the tried and true rather than gamble on the unfamiliar. Also, if you have company, you don't want to fumble your way embarrassingly through uncharted celestial real estate. Plus, we're all inclined to do what's easiest. We want our splendors handed to us. We'd rather not work our way through the galaxy when it's more effortless to take the laid-back approach. That means our best-lubricated brain circuits will turn to their favorite, well-tempered celestial goodies. Indeed, why look further when nothing impresses people more than the moon, that old standby that taxes our cerebral cortex no more than locating the fridge.

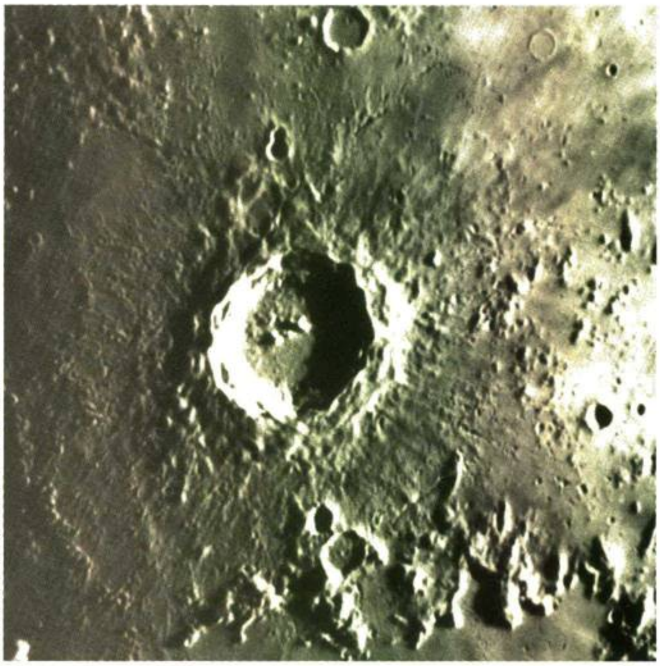
The problem, of course, is that competing with our lethargy is our desire for novelty and excitement. After awhile, Jupiter's belts and four moons start to look like the same tedious beer commercial. Been there, done that. No wonder, for many people, the telescope ends up in the attic.

Here's one solution. Don't bother finding new things in the sky; at least not tonight. Instead,

FANTASTIC

by Bob Berman





(left) Lick Observatory; (right) Christian Arsidi

follow a few stone-simple tips and squeeze new excitement out of the old targets, the ones you've seen over and over and over.

But how can this advice zero in on your favorite sky objects?

Come on! We're one tribe. We think alike. You love Saturn and Albireo, and you don't bother with M34 or M100. Right?

You'll show people M13 (Hercules Cluster) or M42 (Orion Nebula), but you don't often show off M22 or M16. You will return to the Double Cluster and the Ring Nebula, but you don't do windows and will not point a telescope toward Uranus. See: We're more alike than you thought.

The all-time greatest reruns in our library of nightly goodies, the things we return to as routinely as if they were opiates, are: The moon (the half moon, since the lighting is best), Saturn, Jupiter, Albireo, M13, and M42.

All of these objects are fun. Now let's see how you can give them new life.

The Moon

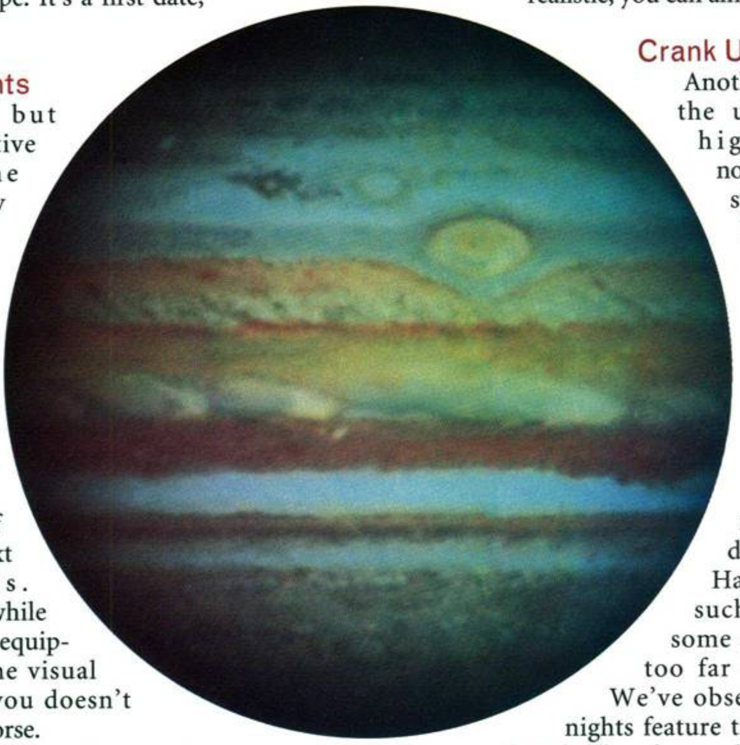
The half moon is always the half moon, right? Well, yes and no. It's true that, thanks to the moon's synchronous rotation, the same features always sit in the same locations on the moon's face, except for slight displacements caused by the wobbles of libration (or libation, if you've gotten to the eyepiece with less than a clear head). The southern section is always pocked like bubbling porridge with hundreds of various sized craters, and a wonderful mountain chain sits smack in the middle. Completing this rugged but repetitious landscape is the fact that sunlight always illuminates the scene from the right.

That's because astronomers around the world routinely observe the first quarter moon. We

You've probably seen the first quarter moon (second from left) many times. But have you ever observed the third quarter moon (second from right), which rises around midnight? By looking at the moon through a telescope during different phases, features such as the crater Copernicus (far left and right) take on a new appearance as the illumination angle shifts.

seldom, if ever, gaze at that other half moon, the third quarter, which has entirely different lighting. Should that make a big difference? You bet. Imagine if you had only seen your home in, say, noonday light. Then one day you get to view your surroundings at sunset. Everything's familiar, but it's wondrously different, deliciously enchanting.

True, there's a price for novelty. You've really got to want newness to see the last quarter moon; it doesn't even rise until midnight, unlike that intimate first quarter friend who rides the meridian at nightfall. But go ahead and sacrifice some sleep. Suddenly the mountains and craters seen at full moon assume a bizarre, unfamiliar pose; a scene so new will elate you, it'll bring back memories of the first time you aimed a telescope at the lunar landscape. It's a first date, all over again.



This image of Jupiter was taken by the Hubble Space Telescope in 1991 before corrective optics were installed. On a night when the air is very steady, crank up the magnification to 300x. You will be able to see almost this level of detail in the eyepiece.
STScI

3-D Delights

A different but extremely effective way to see the moon anew is by using a binocular eyepiece — you can try this on Jupiter and Saturn as well. If you imagine that using two eyes doesn't heighten the experience, just try closing one of them for the next five minutes. (Don't do this while operating heavy equipment.) See if the visual world around you doesn't change for the worse.

People sometimes point out that a binocular arrangement through a telescope is a sham because the image for both eyes is channeled from a single source; identical images appear in each eyepiece. Those experienced with the principles of stereopsis know that one image has to be slightly displaced in order to get a true three-dimensional effect.

Usually that's true. In astronomy, it isn't. When looking at distant objects, both eyes point parallel to each other; there's none of the "cross-eyed" business of eyes peering at slightly different angles that you get when focusing on nearby subjects. So an eyepiece that splits a single image to deliver it identically to both eyes will also trick the brain into thinking that it not only is indeed seeing in 3-D, but also that it's viewing something very distant — which in fact is the case with any celestial target.

The moon at 100x appears to lie 2,200 miles from your eyes. (This, incidentally, happens to be the moon's diameter. So, amazingly, a modest 100-power eyepiece makes the moon seem to hover just one of its own widths from you!) That's dramatically close — but it's still far enough for there to be zero parallax as far as your stereo vision is concerned.

To see the moon or Jupiter float in front of you in 3-D, with all the realism of life itself, transforms the experience like nothing else can. The only caveat is that with planets, and especially Saturn — which is typically 10 times less bright than Jupiter — you should have at least a 6-inch scope so that the reduced brightness caused by dividing the light doesn't diminish its glory. Also, a night of steady seeing is important. Blurriness in 3-D just doesn't make it: "Oh look, George, that smudge is so realistic, you can almost touch it."

Crank Up the Power

Another novelty: Try the unthinkable — high power. As novices, most of us started out with a Napoleonic obsession with power, which some manufacturers happily pander to by announcing that their 2-inch department-store refractor can deliver 600x. Having gotten past such megalomania, some of us have gone too far the other way. We've observed how most nights feature turbulent air that doesn't allow for much over 150x or so, and so we habitually consider that the upper limit for sharp viewing. It's the creature-of-habit thing, again. We forget that we've got a Barlow or telenegative lens lying around somewhere that can be hooked up to that trusty 12.5mm or 20mm eyepiece to deliver something like 300x.

Try it on a still, perhaps slightly misty night when the stars are rock steady. With 300x, Jupiter looks eight times larger than the moon appears to the naked eye! Breathtaking. If you have an 8-inch or larger scope, the optics can easily handle that magnification without degradation of image; it's all up to the night's seeing. True, sharpness and brightness are somewhat diminished, but you'll notice things like limb darkening and shadows of satellites and transient "surface" detail that simply don't show up with your 80x eyepiece.

With Saturn, now that its rings have tilted more forcefully away from edgewise, the Cassini division is clearly reemerging for the first time in several years. It too deserves the highest possible power the night can bear.

Alter Your Reality

Colored filters help bring out planetary detail and subdue the glaring brilliance of the moon. Using them is a matter of taste, and they do indeed make those old targets look "new." (Show a blue or orange-colored globular cluster to visitors, and you'll definitely get an excited reaction, especially if they're old enough to remember the 60s.) It's a personal matter, but for me, filters impose a distracting, artificial presence on what is inherently a stunning natural scene. I think screw-on eyepiece filters are best used by serious planetary observers obsessively hunting for transient detail. One possible exception is Mars, a world where things look better through rose colored glasses. Again, it's a judgment call, but I think an orange or red filter on Mars (which isn't even the best shade to bring out maximum surface detail; green or blue is) makes the planet look more dramatic and brings it more in line with what visitors expect to see.

Another hint for planetary observers is to employ any of the fine computer programs or, in the case of Jupiter, consult the charts in *Astronomy* to see what satellite configurations to expect — ahead of time. Then at the eyepiece, those bright dots take on the excitement of going from points to identifiable worlds.

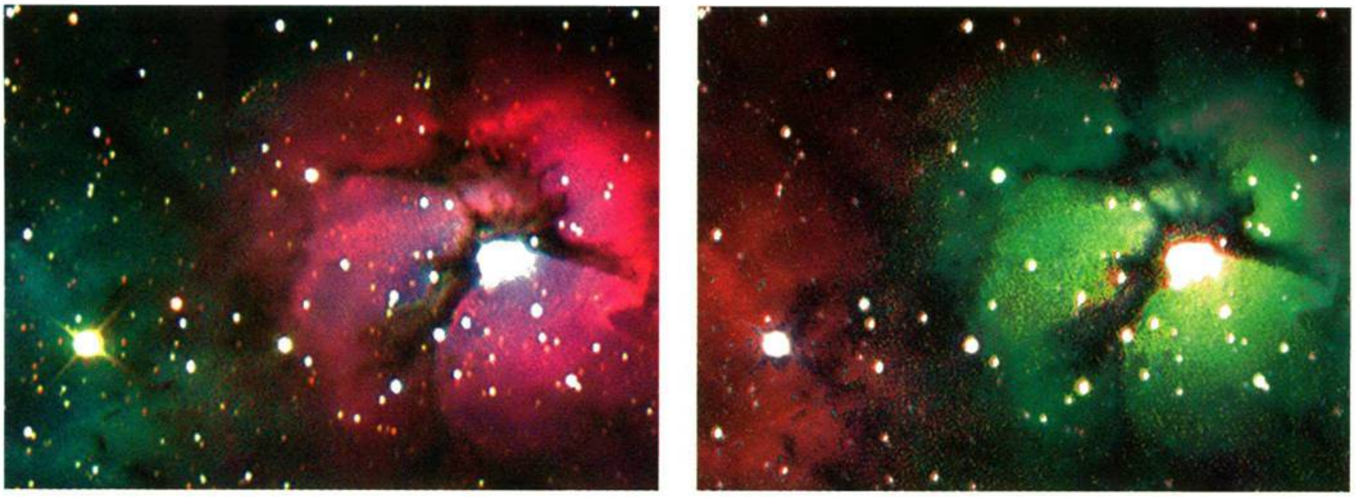
With colorful double stars, limit each observing vignette to five or ten seconds. The eye becomes inured to colors after a short time, and the first short "take" will always be the most dramatic. It's a case where less is more. Also, using a reference such as *Burnham's Celestial Handbook* (see "Celestial Navigator," page 50), look up the actual separation of the components ahead of time so that these mere dots acquire some meaningful dimension. Knowing that Albireo's two contrasting jewels sit about 4,500 Earth-sun distances apart allows the full celestial reality of the scene to hit home. Then, the conceptual mind (which observes "two suns separated by 60 solar-system diameters") merges with the eye ("pretty colors!") to yield an experience greater than either component.

Finally, to really see things in a new way, try photography. Film magically delivers a "new look" to old targets by altering both appearance and color balance. It's more than watching the emergence of previously unseen detail; the visually observed greenish cast of the Orion Nebula completely vanishes on film due to overexposure and gets replaced by rich blues and reds. Nebulae and galaxies, more than any other class of objects, receive a total make-over. We seldom can afford plastic surgery for ourselves or our companions, much as we might wish for it either, but our favorite celestial friends instantly get a face lift via prime focus photography.

Using a CCD setup allows even greater manipulation, along with the pleasure of instant gratification. Watching your monitor, you can tweak the image until it no longer resembles anything nature has ever concocted. Or you can simply enhance low-contrast areas. In other words, cheat the way the professionals do. Add false color to produce images like the ones NASA and JPL routinely release to the press. If a visitor stares in disbelief while you spend an hour making the Trifid Nebula look like a Grateful Dead poster, so what? You can always rationalize that distant alien life forms may perceive colors in just those ways.

There you have it. Now you know how to stick to your guns, refuse to compromise your principles of sloth, and never look at anything new — yet still enjoy new experiences.

Hmmmm, I think I'll have the steak — the same as last time. ■



Gregory Terrance

Using CCDs, you can have fun manipulating the colors of objects such as the Trifid Nebula (M20) so they appear any way you want.

Bob Berman is Director of Overlook Observatory near Woodstock, New York, and Storm King Observatory in Cornwall, New York. The paperback version of his book, Secrets of the Night Sky *was published in 1996, by HarperCollins. His last article for* Astronomy *was "A Lesson from Hollywood" in the October 1997 issue.*

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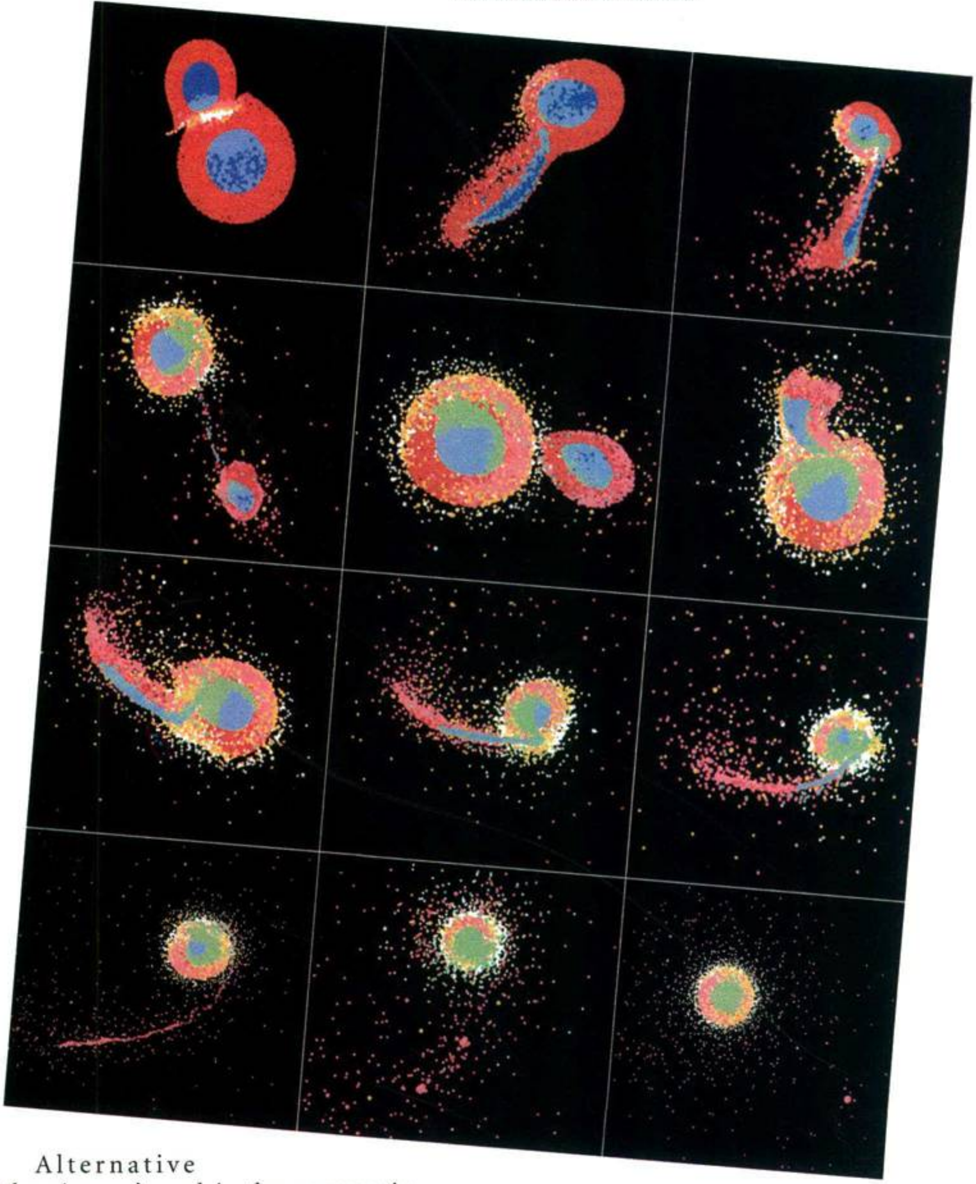


As this computer simulation shows, a large planetesimal smashed into Earth shortly after the planet formed, blasting mantle material into orbit. This material later coalesced to become the moon.

A. G. W. Cameron (Harvard University)

Q: The current theory of the moon's formation is that it was created about 4.5 billion years ago when a Mars-sized world struck Earth. Some of the debris in orbit around Earth gradually reaccumulated to form the moon. What is the evidence that supports this theory, and are there any alternative theories? — *Daniel Del Valle, Aguadilla, Puerto Rico*

A: The idea that the moon formed from a giant collision now seems to be the leading theory to explain its existence (see "How to Make Earth's Moon," page 24). One of the most puzzling properties of the moon is that it has much less iron than does Earth, as evidenced by its much lower mean density, 3.3 times that of water as compared to Earth's 5.5 times that of water. Another way of saying the same thing is that the moon is made of material that looks more like rock from Earth's mantle than like the overall composition of Earth. Thus, one piece of evidence in favor of the impact idea is that the impact blew off rocky material from Earth's mantle (and from the impactor's mantle) and this debris formed the moon. In this scenario, the iron cores of both bodies had already formed, and core material did not make it into Earth orbit. This explains the moon's lack of iron.

Another piece of evidence, from the lunar samples, is that the moon's composition of certain isotopes exactly matches that of Earth, but it doesn't match those of bodies from elsewhere in the solar system. Still another positive feature of the collision theory is that it explains the moon's lack of water and lightweight volatile compounds: The impact heated the debris to high temperatures, and all volatiles turned to gas and escaped into space.

Alternative theories can't explain these properties. One older theory, that the Earth and moon grew side by side, doesn't explain why one contains iron and the other doesn't. Another old theory, that the moon formed far away and was captured by Earth, violates the isotope evidence that they formed in the same location. A third old theory, that the moon spun off the outer layers of Earth, violates energy and angular momentum considerations. The impact seems to be needed to blow the debris into orbit. — *William K. Hartmann, Planetary Science Institute*

Q: The Mauna Kea summit in Hawaii has an altitude of 13,800 feet (4,200 meters). This altitude

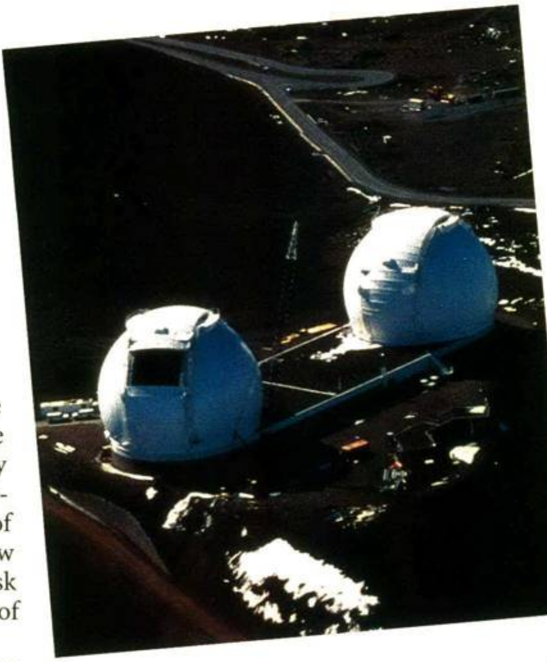
generally requires acclimatization or oxygen. Is the observatory automated and does it only require a few acclimatized technicians while the astronomers work by remote controls, or do they use oxygen? *— Joe Boyd, Susanville, California*

A: With an atmospheric pressure only 60 percent that at sea level, the summit of Mauna Kea clearly presents unusual physical challenges. We walk slowly, drink lots of fluids, watch out for our fellow workers, and write down every task because short-term memory is one of the first casualties of high altitude.

At the W. M. Keck Observatory, we do not have oxygen-enriched work areas, although both control rooms were designed with sealable doors, and the engineering spaces have room for oxygen-generating equipment. Installation costs and the annual $50,000 cost just for electricity were high but weren't showstoppers. The clincher against installing the equipment is the tendency of astronomers and observatory staffers to leave and re-enter control rooms many times during a night's run — to walk outdoors and see the stars, use the rest room, get coffee, or just walk down the hallway for a stretch. The long-term physiological effects of repeatedly exiting and re-entering a high-altitude, oxygen-enriched area remain unknown.

Newcomers to the summit can sometimes be found in a corner of the medical room, sucking furtively on an oxygen bottle. Relief is brief. Then the King Lear syndrome slams home: Breathe pure oxygen, feel great; lose the oxygen and feel really, really bad. Even worse, by sneaking hits, one kills all progress the body has made toward acclimatization — our ultimate tool for performing well at high altitude.

Before ascending to the summit, all observatory shift workers stop at the 9,000-foot base camp, Hale Pohaku, for a half-hour or so to begin acclimatization. Astronomers spend up to 24 hours there, lest they fly in from wherever, race to the summit, and keel over. Astronomers and telescope operators are required to stay at base camp if they are observing at the summit.



Observatory in thin air: The twin 10-meter Keck Telescopes rest atop the majestic 13,800-foot summit of Mauna Kea on the big island of Hawaii.

W. M. Keck Observatory

For the Keck Observatory's 30 employees assigned to work regularly on the summit, there is one law that is never forgotten: No matter how many shifts we've worked on the summit — and some have worked thousands — everyone eventually will have a bad day and suffer from altitude sickness. Mild symptoms include a pounding headache, nausea, dizziness, and lassitude. More serious symptoms include the dry barking cough indicative of pulmonary edema or the irrational behavior, accelerating headache, and partial paralysis of cerebral edema. All these symptoms, and more, have presented themselves in the past few years.

Infrequent visitors — such as astronomers who come only a few times each year — typically register blood-oxygen levels of 65 percent within 90 minutes of arrival. Levels rise gradually, and stabilize, at about 80 percent after three hours. For our regular workers, blood oxygen dips initially to about 80 percent, then rises to a more robust 93 to 94 percent. The body apparently acclimatizes more quickly the more often it is exposed.

The Keck Telescopes are not automated, but in the first six months of 1997 the percentage of astronomers observing remotely from Waimea headquarters (48 miles distant at an elevation of 2,500 feet) jumped from 25 to 90 percent. — *Andrew Perala, W. M. Keck Observatory*

Q: How big and bright would Jupiter appear from Earth if it came as close to us as Mars does? *— Dennis A. Barnes, Seneca, South Carolina*

A: Backyard observers around the globe are waiting for August 2003, when Mars will make its closest approach to Earth in more than a thousand years. Swinging within 35 million miles (56 million km, or 0.37 astronomical unit) of Earth, the diminutive planet will glow brilliantly at magnitude –2.9 and swell to 25.1" across.

What would happen if giant Jupiter came that close? First, it would shine at magnitude –10.8 (slightly brighter than a quarter moon). Yet all that brightness would be packed into a disk measuring 530" across, or roughly 30 percent the moon's size. Second, the Great Red Spot would just be visible to the naked eye under good conditions, and each of the four Galilean moons would shine brighter than Sirius, the brightest star in the night sky. In fact, the four moons would appear large enough (12" to 19" across) to show detail in a typical backyard telescope.

But there would have been a down side if Jupiter had formed in Mars's present orbit. Its immense gravity would have wreaked havoc on the rest of the inner solar system (as it does now in the asteroid belt). It would have made it impossible for any large planet to form at Earth's present location. So while it's nice to think hypothetically about what Jupiter would look like if it came much closer to Earth, it's nice to know that it doesn't. — *Richard Talcott*

CONTACT INFO

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53186. Please tell us your full name and where you live. *Astronomy* regrets that due to the large volume of mail, we are unable to publish answers to all questions or respond to each one individually.

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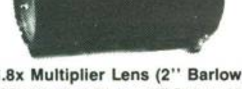

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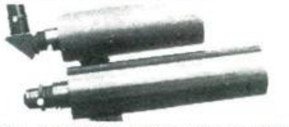

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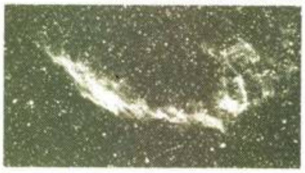

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†U.S. Patent 4,473,636

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Pentax 6X7 **add $129;** Pentax 645 **add $149**

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Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

In the Eyepiece *of the* Beholder

A new eyepiece series from Pentax holds its own against the competition.

by Steve Edberg

All photos *Astronomy*: Jim Forbes; Eyepieces courtesy of S & S Optika and Pentax

FROM THE MOST EXPENSIVE, custom-built telescope all the way down to that department-store refractor many of us snicker at, the quality of the eyepiece an astronomer uses can make or break the image he or she sees. (Try it: Attach a good eyepiece to one of those department-store refractors and you may be surprised.)

Apparent field of view and eye relief seem to receive the focus of attention when astronomers discuss the quality of an eyepiece. Actually, many more parameters should be considered as well. Star image quality, light transmission, contrast, glare, color aberrations, and distortion ("fishbowling") all contribute to the quality of the view and to an observer's overall satisfaction.

As if that's not complicated enough, one optical parameter of the telescope itself comes into play: the focal ratio (f/number). The same eyepieces in fast optical systems (those with low f/numbers) may exhibit a noticeable difference in image quality in slow systems (those with high f/numbers).

Courtesy of Lumicon in Livermore, California, I got to test a set of recently released premium eyepieces, the Pentax SMC-XL Series, against older eyepieces long considered the standards of the field. The comparisons were enlightening; all of the eyepieces got a chance to show both their best characteristics and their faults.

I set up to observe at a dark-sky site in Lockwood Valley, California, using an 11-inch f/10 Schmidt-Cassegrain telescope (SCT) and a 6-inch f/4 Newtonian richest field telescope (RFT). I also observed from my backyard, which overlooks the Los Angeles basin, using a 4-inch Maksutov-Cassegrain to study small-telescope star images and an 8-inch f/10 Schmidt-Cass to monitor behavior with planetary targets. The telescopes all have good optics, and, except in the case of the 4-inch Mak, I compared the Pentax eyepieces against others in each test. (You can't really judge an eyepiece without comparing it to another.)

My collection of comparison eyepieces included Vixen Lanthanums, Clavé Plössls, and Televue Panoptics, Naglers, and Wide Angles with the same or nearly the same focal lengths as the Pentaxes. The Pentax eyepieces had focal lengths of 40mm, 28mm, 14mm, and 7mm. (The series also includes focal lengths of 21mm, 10.5mm, and 5.2mm.)

No set of eyepieces stands out in all categories. The Pentaxes, in keeping with this tenet, are a mixed bag, but they certainly left a good impression.

During my testing with the 11-inch SCT at the dark-sky site, it quickly became obvious that for deep-sky observing the Lanthanums and Clavés, with their apparent fields of view in the 50° range, could not compete with the viewing pleasure offered by the wider fields of

view of the Televue and Pentax eyepieces. The Pentaxes all have 65° apparent fields of view, while the Televue eyepieces are in the 68° to 82° range, depending on the model.

The 28mm Pentax showed fainter stars more easily than a 28mm Panoptic, 25mm Lanthanum, or 24mm Wide Angle. The images also suffered from less distortion when I used the Pentax eyepiece than with the Panoptic or Wide Angle: Stars followed straight lines when sweeping through the field, as opposed to curved lines in the other wide-angle eyepieces. The Panoptic has a wider field of view than the Pentax and showed better star images at its edge. In the RFT, the star images at the edge of the Pentax field of view were acceptable and the lack of distortion made for a nice view during sweeps of the sky.

A Nagler 13mm also has a wider field of view than the Pentax 14mm, but its transmission was not as good. In the SCT, the star images at the edge of the field were good in both, but the Pentax suffered a bit in the RFT.

At 7mm, a Nagler has a wider field of view than the Pentax but notably less eye relief, and the Pentax again has better transmission. Star images were not as good at the edges in the Pentax when used in the 6-inch RFT.

I didn't have an equivalent eyepiece to match with the 40mm Pentax so I opted to compare it to a Televue 32mm Wide Angle eyepiece. The Televue showed a wider true field of view (not a surprise), and other results were consistent with the previous behavior of the Pentaxes: better transmission and poorer edge images in the RFT.

In summary, Pentax triumphed over the competition in terms of viewing faint stars. And when sweeping the sky, the curving motion of stars caused by distortion wasn't noticeable. On the other hand, the quality of the star images at the edges of the fields of view was generally better in the Televue products, at both f/10 and f/4. I did note that a Celestron coma corrector in my 6-inch f/4 RFT seemed to help images overall. Throughout my testing, I was impressed by the eye relief offered by Pentax.

When it comes to lunar and planetary viewing, there are different concerns to consider. Field of view, especially at high powers, counts for less here (though it still counts for something). Where moons and planets are concerned, what really matters is how your eyepiece measures up in terms of glare and internal reflections.

I decided to use Lanthanums, which proved their worth during Comet Shoemaker-Levy 9's collision with Jupiter, as comparison eyepieces in this delicate observational arena.

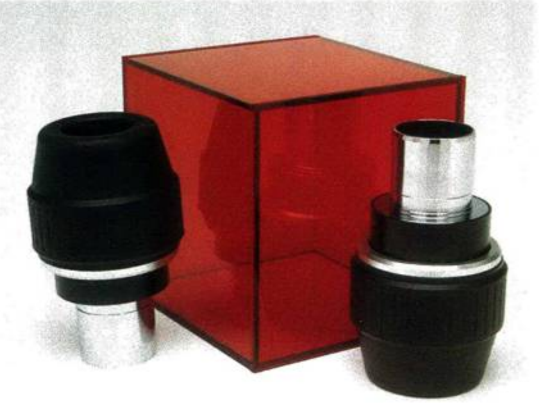
The 7mm Pentax provided a great glimpse of Jupiter's four satellites as well as a moon's shadow on the planet's disk itself. I had no trouble with internal reflections when I used the Pentax 14mm and 7mm eyepieces, and their performance was comparable to or better than the 15mm and 9mm Lanthanums. The Pentax 28mm showed slight internal reflections when the source was off-axis, but its comparison eyepiece did no better. Meanwhile, the 28mm provided good contrast.

In terms of glare, the 28mm, 14mm, and 7mm Pentax eyepieces performed on the same level as the Lanthanums. I was surprised, though, to find that the Pentaxes showed notably less color across the field of view.

The Pentax 40mm showed no significant glare when compared to the 32mm Wide Angle and a two-inch 40mm orthoscopic.

Due to their large outer diameters, I couldn't fit the Pentaxes into any of my eyepiece projection photography apparatuses. In truth, eyepieces are optimized for visual observing and are not the best choice for photography anyway.

The Pentax eyepieces all come enclosed in square, transparent, slide-click closing boxes; all the eyepieces have plastic covers on both ends. The 7mm, 14mm, and 28mm oculars had 1¼-inch plumbing, while the 40mm had the two-inch standard. Of particular note were the "eye-stops." A coarsely spaced but smooth thread permits the position of the "eyehole" in front of the eyepiece lens to be adjusted to the observer's most comfortable position, whether you choose to wear your glasses or not. This works wonderfully thanks to the long eye relief offered by the Pentaxes.



All in all, the performance of the Pentax SMC-XL eyepieces certainly made me want to add them to my collection. The series stands to become the standard of comparison for the next generation of eyepieces. ◼

Steve Edberg is a persnickety eyepiece user and executive director of the Riverside Telescope Makers Conference.

Standard Specifications

Eye relief
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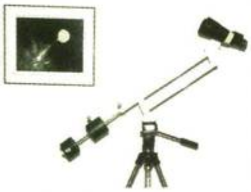

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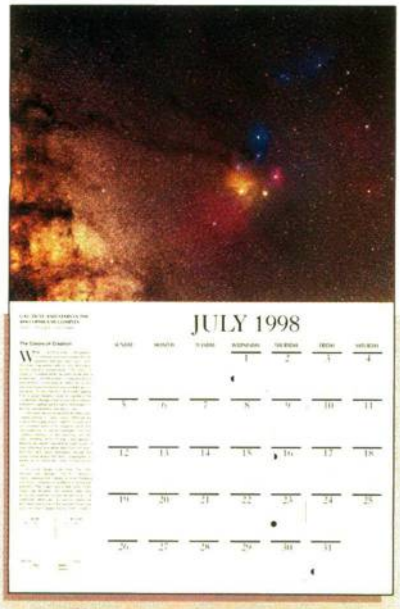

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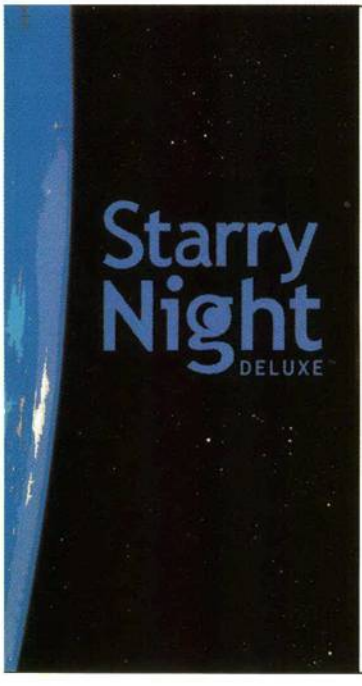

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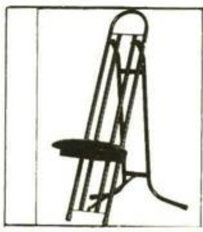

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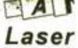

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Take Me to a STAR PARTY

Nebraska Star Party/Vic Winter

Try some star-gazing to brighten up the family vacation.

by Patricia A. Kurtz

As varied as entrees at a good restaurant, star parties can satisfy any discriminating palette. Obviously, a star party's main course is observing celestial objects. Since these are most delectable after sunset, many party-goers try to sleep during the day and observe at night. As the trend toward enticing entire families to observing-vacations grows, you might notice blurry-eyed astronomers stumbling about in the dark of shade trees at high noon, while chasing after their less-than-nocturnal family members. Some of the unique events may tantalize even the most seasoned amateur astronomers.

STUDENTS ARE THE PRIORITY AT TABLE MOUNTAIN

"I approached the telescope field about midnight and was awed by the hundreds of murmurs and numerous telescope silhouettes that greeted my senses. These sights and sounds are the spirit of the event — a field full of people from all walks of life peering through an enormous variety of telescopes, ooh-ing and aah-ing at the sights in the heavens," says Kerry Winston, staffer at the Table Mountain Star Party (TMSP).

Attendance has grown dramatically since this star party originated in 1980 to more than 1,100 people attending in August 1997. The TMSP site may be primitive (it's near Ellensburg, Washington), but the activities are far from it.

Speakers in 1997 included telescope builder John Dobson, astrophotographer Jack Newton, and archaeoastronomer John Rudolph. About $4,500 worth of prizes were awarded — including eyepieces, CD-ROMs, solar screens, filters, star charts, books, binoculars, and four Celestron telescopes. During the 2½-day event, meals were available at a cooking shack. In fact, with the optional Friday and Saturday meal plans, some folks didn't bring any food to the star party at all. Not only was food abundant, the on-site espresso vendor went through 60 gallons of milk!

Vendors told TMSP staff members that theirs is the most beautiful site on the circuit. But it's the family atmosphere and the student astronomer program that makes the TMSP the third most popular star party in North America. The student program offered games galore including the Big Bang Run, a celestial scavenger hunt, Astronomy Jeopardy, and a narration of constellation mythology, complete with props.

A first-of-its-kind event is on the menu for 1998. Julie Lutz, director of the astronomy department at Washington State University and former National Science Foundation Chair, has helped TMSP create an accredited seminar for science teachers. Lesson plans will be provided for teacher/student interaction, and students will have an opportunity to take on new challenges in astronomy by experiencing the course. Attending amateurs will contribute by providing expertise and equipment.

If the scheduled daytime activities aren't your cup of tea, you can hike, camp, bike, watch nature, and enjoy the outstanding alpine views. Seattle is 3½ hours away. Mt. Rainier and other Pacific Northwest volcanoes are an easy day trip, and the historic mining town of Liberty, Washington, is just a 45-minute drive.

The skies aren't bad, either. Like many great sites, the limiting magnitude is about 6.5. Observers enjoy many views including the spikes in the rings of Saturn, the swirls in Jupiter's belts, and the knots, twists, and strings of 3-D filaments in the Veil Nebula. This star party has blossomed into an event to anticipate. The 1998 festivities will be held from July 23 to 25. Contact the Table Mountain Star Party, P.O. Box 785, Puyallup, WA 98371; e-mail, tmsp@triax.com; website, http://www.tmspa.com.

CANOE THE MILKY WAY IN NEBRASKA

Aside from its velvet black skies, the Nebraska Star Party (NSP) boasts a canoe/tubing trip down the scenic Niobrara River near Valentine, Nebraska.

Last year's expedition turned into a six-hour water fight as nearly 200 participants attacked each other with balloon slingshots and waterguns. People have become increasingly creative over the years, building floating fortresses of connected innertubes and camouflaging themselves in the tall grasses, then deluging unsuspecting water travelers in sneak attacks.

In only four years, attendance quadrupled by 1997, according to a representative of the Prairie Astronomy Club (PAC). These Nebraska party-planners attribute skyrocketing participation in part to the numerous daytime activities available for kids of all ages.

Boating, fishing, and swimming are popular activities at Merritt Reservoir where the star party is held. An ice cream social and beach party with a barbecue, games, and dozens of door prizes highlighted the 1997 events. Daylight talks ranged from "Observing Occultations" to "Telescopes in Education." Additionally, catered meals were available.

For observers, however, the biggest draw to the NSP is the sky. In 1995, amateur astronomer Dave Nash sketched stars to a naked-eye magnitude of 8.2 in a portion of the constellation Draco. Looking like a true edge-on spiral, the Milky Way's brilliance casts shadows on the ground. And with 7x50 binoculars, David Scherping of the PAC can see the entire Veil Nebula. He adds that there is no visible light pollution at the NSP site.

Organizers are committed to making each star party special and enjoyable for everyone who attends. Mark your calendars for this year's party from July 18 through 25. Questions should be directed to Tom Miller, 3400 N. 102nd Street, Lincoln, Nebraska 68527; telephone, (402) 466-4170; e-mail, tmiller232@aol.com; website, http://www.4w.com/nsp.

GRAND CANYON EXPERIENCE

When you combine striking skies and terrestrial splendor and mix them briskly with enthusiastic

Grand Canyon Star Party

Dean Ketelsen

Table Mountain Star Party

Mike Fry

public-oriented astronomers, you've followed the recipe for the Grand Canyon Star Party (GCSP), held at the Grand Canyon in Arizona, to a tee.

Led by members of the Tucson Amateur Astronomy Association (TAAA) and the National Park Service, this event caters to all creatures on two legs within hailing distance. It succeeds in giving many people their first views of some of the sky's greatest wonders.

Sun-watching is accomplished with specially fitted telescopes on the rim of the gigantic canyon by day and with slide-show presentations after dark. Yavapai Point is famous for its spectacular sunsets and attracts thousands of visitors to its breathtaking heights. When the curtain has set on the daytime spectacle, visitors are invited to partake in a celestial display by night.

One observing site is not enough for this crew. They use the Grand Canyon's north and south rims to make sure everyone is satisfied. Dozens of volunteers share their knowledge and telescopes with hundreds of park visitors from around the world. Last year folks were treated to Mars and the moon at 700 power through Utah amateur Mike Spooner's 9-inch folded refractor. Mars gave up a wealth of detail, according to Dean Ketelsen of Tucson, and visitors flocked at the eyepieces to watch the moon's terminator creep slowly across crater floors.

John Dobson and Barry Hirrell attended the GCSP along with a contingent of their fellow San Francisco Sidewalk Astronomers. Both gave well-received talks; as usual, Hirrell's closing presentation was a highlight of the event, and inspired many first-timers to look through the telescopes.

Is This Your First Time?

Unless you live in Hollywood, black-tie dress is a bit formal for the average star party. Besides the many variations on themes of these auspicious events, there are some preparations and rules of etiquette which, if followed, will enhance the party-goer's experience:

- Leave animals at home unless they are well leashed.
- Be prepared for a wide range of temperatures. While observing, dress in layers — don't forget your hat, gloves, and boots.
- Bring insect repellent.
- No white light after "lights-out." Only red-light flashlights should be used. (This includes flash photography — don't even think about it.)
- If you have binoculars or a telescope, feel free to bring them. If not, many folks are happy to share. Wait your turn in line.
- Never use a telescope before asking the owner's permission.
- Above all — enjoy yourself and have a good time.

A unique star party indeed, the GCSP is a must-attend for anyone who loves sharing astronomy and anyone who loves a fantastic view. This year's event is slated for June 13 through 20. Contact Dean Ketelsen for details at 1122 E. Greenlee Place, Tucson, AZ 85719; telephone, (520) 293-2855; e-mail, ketelsen@as.arizona.edu; website, http://www.primenet.com/~lwilson/taaa/taaa.html.

STARS OF ALL KINDS SHINE AT STARFEST

An astronomers' spoof of *The Tonight Show* was the featured presentation at the 16th annual Starfest, held near Mt. Forest in central southern Ontario from August 7 through 10, 1997. Author Terence Dickinson hosted the show and told the crowd that the usual host had been abducted by alien terrorists. With *Star Wars* music enhancing the atmosphere, Dickinson interviewed comet discoverer Tom Bopp and NASA's Fred Espenak.

This class-act event organized by the North York Astronomical Association (NYAA) strives to balance innovative and leading-edge programming for both advanced and novice attendees.

Texas Star Party

Terry Atwood

Last year's daytime talks ran parallel with technical talks on megapixel CCD cameras and CCD imaging in one tent. In another, presentations were given on choosing and using a telescope, touring the universe through binoculars, and selecting star charts.

With Kidfest, Starfest caters to the younger generation as well. Young voices broke the early Saturday morning quiet as eager participants in the youngest age group (three- to five-year-olds) were assigned roles as planets, moons, or asteroids in the solar system. With some adult help, the children lined up in the planetary orbits and completed one orbit around the sun with spectacular results.

Not to be outdone, the six- to eight-year-olds participated in an active round-table discussion about the planets in the solar system. Even the attending adults were challenged by questions answered by the children. Later, the oldest group studied and acted out various Greek and Roman mythologies.

Although Kidfest is a big draw for many at Starfest, most people come for the stars, which are easy to see; the limiting magnitude is about 6.5. Telescopes nestle in a 60-acre

Additional 1998 Star Party Dates

Please include a self-addressed, stamped envelope when writing the groups for information.

WINTER STAR PARTY/JANUARY 26 – FEBRUARY 1

Held in the Florida Keys and sponsored by the Southern Cross Astronomical Society. Contact Therese Rubenstein and Mike Barrs, 3403 Poinciana Avenue, Miami, FL 33133; e-mail, wsp@mangonet.com; website, http://www.scas.org/wsp.html.

PEACH STATE STAR GAZE/MARCH 26 – 29

Held at Camp McIntosh, Indian Springs State Park in Jackson, Georgia and sponsored by the Atlanta Astronomy Club. Contact Ken Poshedly, 3440 Everson Bay Court, Snellville, GA 30278; (770) 979-9842; e-mail, ken.poshedly@mci2000.com.

TEXAS STAR PARTY/APRIL 19 – 26

Held at the Prude Ranch in Ft. Davis, Texas. Contact TSP Registrar, 1326 Mistywood Lane, Allen, TX 75002; email, KASTRO@aol.com; website, http://www.metronet.com/~tsp/index1.html.

RIVERSIDE TELESCOPE MAKERS CONFERENCE/MAY 22 – 25

Held at Camp Oaks, near Big Bear, California. Contact RTMC, c/o Fox & Stephens, CPAs, 9045 Haven Avenue, Suite 109, Rancho Cucamonga, CA 91730; (909) 948-2205; e-mail, robert_stephens@eee.org; website, http://home.sprynet.com/sprynet/hrmeyer/rtmchome.htm.

MASON DIXON STAR PARTY/JUNE 19 – 21

Spring Valley County Park, near York, Pennsylvania. Sponsored by York County Astronomical Society. Contact Jeri Jones, 400 Mundis Race Road, York, PA 17402; (717) 840-7226; e-mail, JLJ276@aol.com; website, http://home1.gte.net/dmdewey/mdsp.htm.

UNIVERSE '98/JUNE 27 – 28

Held at the Hyatt Regency Albuquerque in Albuquerque, New Mexico. Sponsored by *Astronomy* magazine and the Astronomical Society of the Pacific. Contact Laurie Keechler, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1100; e-mail, lkeechler@aspsky.org; website, http://aspsky.org/u98/u98.html.

ALCON '98/JULY 22 – 25

Held in French Lick, Indiana. Sponsored by the Astronomical League. Contact Sally Hardin Lambert at 2000 Waterfront Plaza, 325 W. Main Street, Louisville, KY 40202-4251; (502) 587-7711; e-mail, 105153.2244@compuserve.com.

STELLAFANE CONVENTION/JULY 24 – 25

Held on Breezy Hill, Springfield, Vermont. Sponsored by the Springfield Telescope Makers, Inc. Contact Stellafane Convention, P.O. Box 50, Belmont, MA 02178; e-mail, tom@solar.njit.edu; website, http://www.stellafane.com.

MT. KOBAU STAR PARTY/AUGUST 15 – 23

Held in Okanagan Valley, British Columbia. Contact Mt. Kobau Astronomical Society, P.O. Box 20119 TCM, Kelowna, B.C. Canada, V1Y 9H2; (250) 764-8478 (Ann Murphy); e-mail, ron@bcinternet.com.

ASTROFEST/SEPTEMBER 11 – 13

Held at Camp Shaw-Waw-Nas-See in Kankakee, Illinois. Sponsored by the Chicago Astronomical Society. Contact Astrofest '98, P.O. Box 596, Tinley Park, IL 60477-0596; voicemail, (773) 725-5618 and press 3.

ENCHANTED SKIES STAR PARTY/OCTOBER 15 – 18

Held in Socorro, New Mexico. Contact the Enchanted Skies Star Party, P.O. Box 743-I, Socorro, NM 87801; (505) 835-0424; e-mail, jmares@admin.nmt.edu; website, http://www.nmt.edu/~astro/essp.html.

OKIE-TEX STAR PARTY/OCTOBER 18 – 25

Held at the Prude Ranch in Ft. Davis, Texas. Sponsored by the Oklahoma City Astronomy Club. Contact Kyle Carr, 7000 Pebble Lane, Oklahoma City, OK 73132-3528; (405) 722-1678; e-mail, seadkins@icon.net; website, http://www.icon.net/~seadkins/okcac.html.

MID-ATLANTIC STAR PARTY/OCTOBER 22 – 27

Held at the Boy Scout Camporee Camp Reeves in Central North Carolina. Contact MASP, 244 Deerfield Road, Apex, NC 27502; (919) 362-5194; e-mail, john@bsa.net; website, http://www.bsa.net/masp/.

IT'S MY PARTY . . .

Astronomy hosts its 25th Anniversary AstroBlast star party at the Rio Rancho Balloon Fiesta Park outside of Albuquerque, New Mexico on Thursday, June 25. Come join the fun and festivities and help us kick off Universe '98 in Albuquerque — registration is free. Camping spaces are limited and require pre-registration. For more information and registration materials, write to AstroBlast, care of *Astronomy* magazine, or e-mail astroblast@astronomy.com.

observing field amid 200 acres of rolling hills. Although many folks camp, this is not exactly a primitive site.

Thirty trailer sites offer full hook-ups, but you can camp in an open field as well. Some areas have electricity. The camp has a swimming pool, a childrens' play area, and fishing, wading, and canoeing in the stream that runs through the property. Local Boy Scouts run a food concession, and on Saturday night the NYAA caters a roast beef buffet dinner.

If that doesn't make your mouth water, a state-of-the-art presentation system enhances the talks. Starfest makes excellent use of slides, computer graphics, and video images, in addition to an enclosed rear-projection system. Some folks take advantage of the eyepiece cleaning station, a booth that makes star charts while you wait, and the Red Light Cafe, which is open all night Friday and Saturday. With all this and more, Starfest is the highlight of the summer for many folks.

For information, contact The North York Astronomical Association, 26 Chryessa Avenue, Toronto, Ontario Canada, M6N 4T5; (416) 761-1798; e-mail, tward@spanit.com; website, http://www.unicom/~nyaa/nyaa0.htm.

Patricia Kurtz, Astronomy*'s Photo Editor, loves to travel and is a star party veteran. She is also organizing* Astronomy*'s 25th Anniversary Astroblast. Check out www.astronomy.com for updates and future star party information.*

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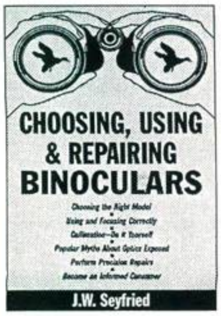

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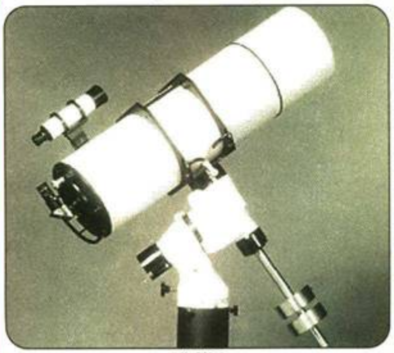

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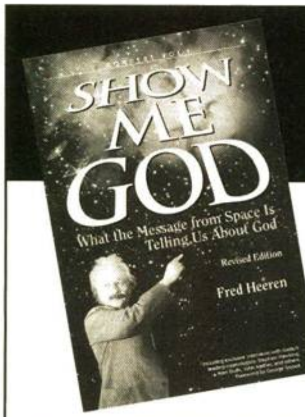

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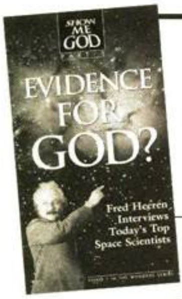

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A BOOKS

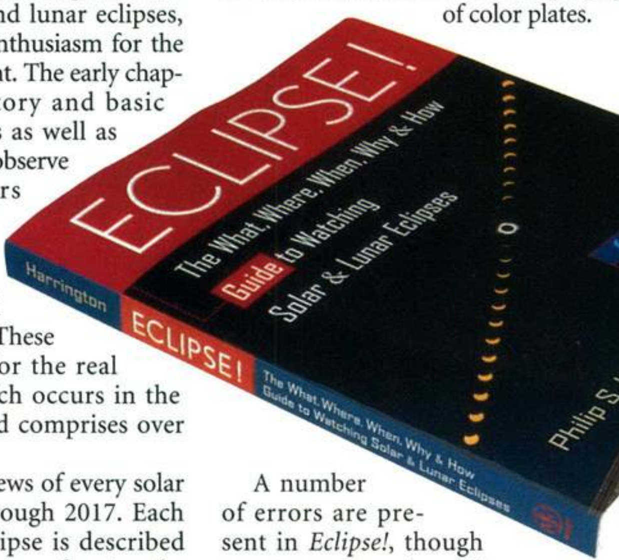
ECLIPSE! The What, Where, When, Why & How Guide to Watching Solar & Lunar Eclipses

Philip S. Harrington, 280 pages, John Wiley and Sons, New York, 1997; ISBN 0-471-12795-7, softcover, $14.95.

► In this ambitious and comprehensive guide to both solar and lunar eclipses, author Harrington's enthusiasm for the subject matter is evident. The early chapters discuss the history and basic mechanics of eclipses as well as equipment needed to observe them. Later chapters describe the various types of eclipses, the demands of eclipse photography, and expedition planning. These topics set the stage for the real heart of *Eclipse!*, which occurs in the final two chapters and comprises over half the book.

We are given previews of every solar eclipse from 1998 through 2017. Each total and annular eclipse is described and illustrated with a map showing the land-based portion of the path. In addition, several tables provide center line coordinates for plotting on your own map, as well as local contact times for five to ten major cities. But the most unique and welcome feature is a weather prospects table giving cloud cover statistics for several locations in or near the eclipse path.

The photographs found throughout the book were made by many photographers using a range of equipment. Thankfully, each photo is accompanied by technical information (i.e. lens focal length, f/number, shutter speed and film ISO). This is invaluable information for would-be eclipse photographers planning their first expedition as well as for seasoned pros looking for new ideas. It's too bad there are no color photographs, but this was probably done to keep the book's price down. Still, the subject matter screams for at least a couple pages of color plates.


ECLIPSE!
The What, Where, When, Why & How Guide to Watching Solar & Lunar Eclipses
Philip S. Harrington
Harrington
ECLIPSE!
The What, Where, When, Why & How Guide to Watching Solar & Lunar Eclipses

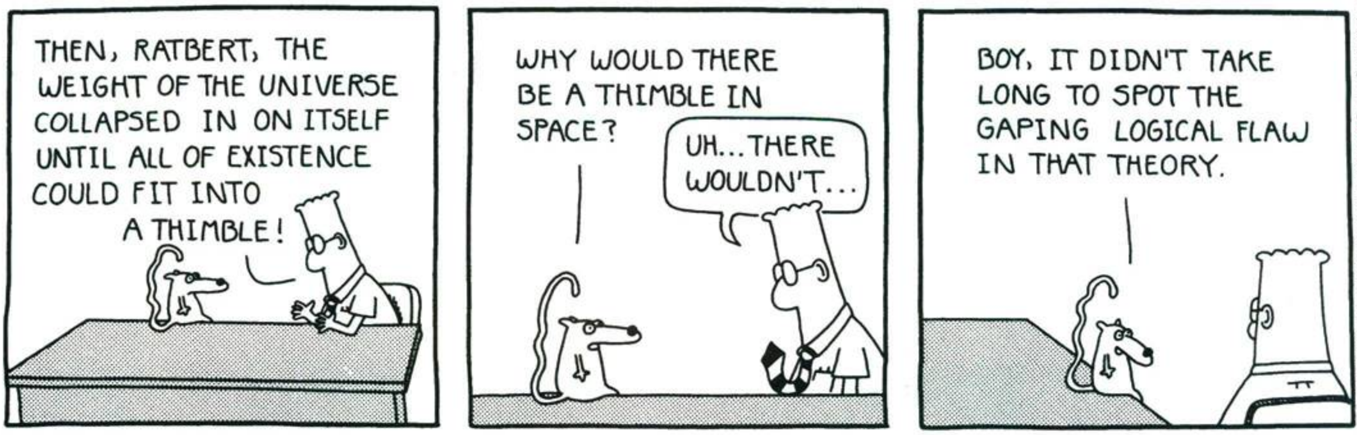
A number of errors are present in *Eclipse!*, though most are not serious. Nevertheless, they may lead to confusion, especially among beginners. Confusion also arises in early chapters where both solar and lunar eclipses are discussed together. These phenomena are so vastly different from each other that it would have made more sense to split them into separate chapters, especially when dealing with observing equipment and photography. It would have been helpful to directly reference other books and magazine articles that discuss these topics in greater detail — a general criticism that holds true throughout the book.

To eliminate another potential source of confusion, here's a hint. I was puzzled when I compared the figures of the moon's path through Earth's shadows with my own eclipse software because it appeared that Harrington's eclipses were occurring at the wrong node. I finally realized that paths in *Eclipse!* are all plotted in ecliptic coordinates instead of celestial. Nonstandard at best, this "feature" isn't noted in the book and promises to confuse more readers than just myself.

Eclipse! covers a great deal of ground, and there in lies its Achilles heel. It tries to be a jack-of-all-trades and ends up being master of none. But in spite of these shortcomings, the book serves as an enjoyable introduction for novices and as a convenient abridged reference of the major events occurring in the next two decades. The concept of combining a basic eclipse guide with a twenty-year preview is commendable. The book's price delivers good value, especially if you plan to buy only one book on the subject. Just be advised that you'll need to turn to other sources to explore the many topics of which *Eclipse!* barely scratches the surface. The book is sure to inspire readers to witness their first eclipse. Just heed the author's warning — eclipses are addictive!

NASA astronomer Fred Espenak publishes bulletins for eclipse viewers.

(continued on page 104)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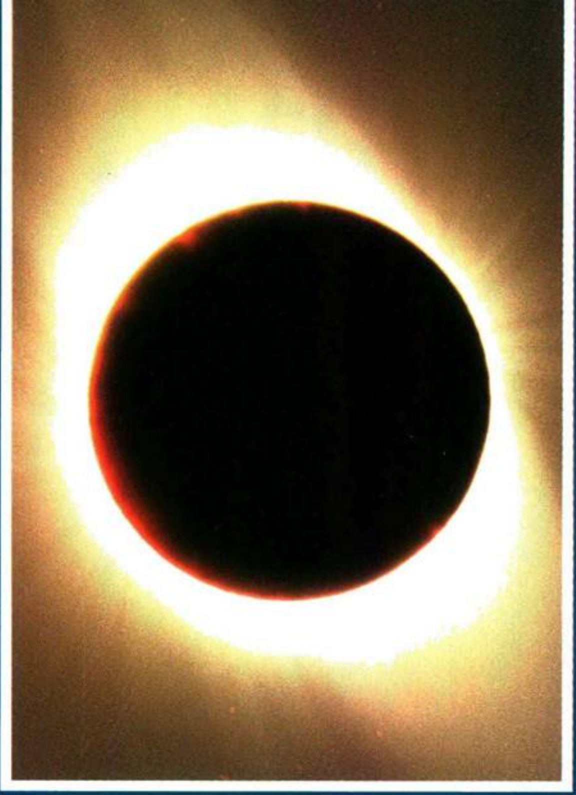

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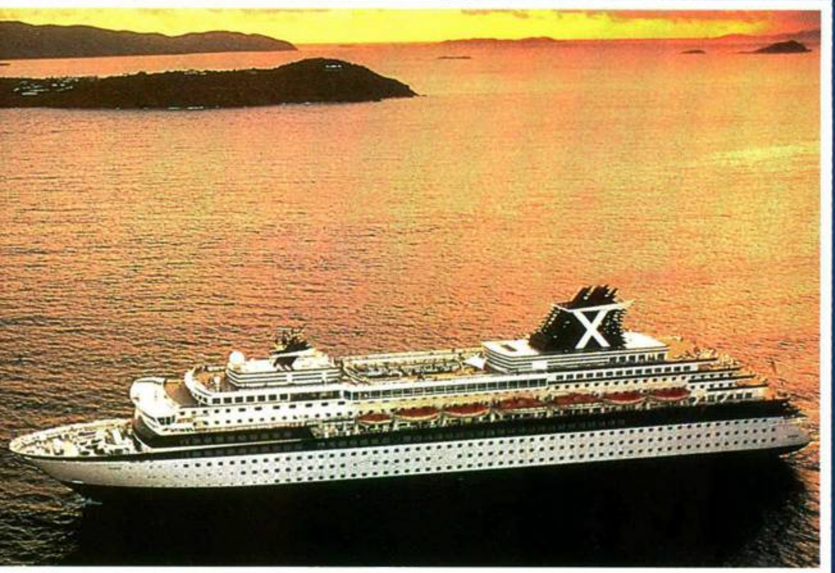

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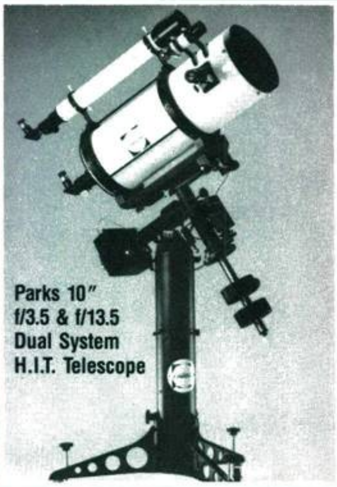

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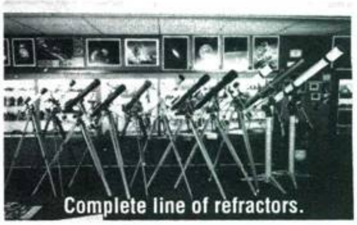

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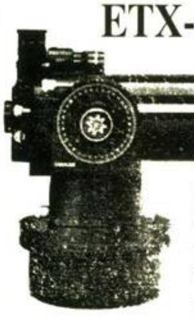

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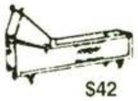

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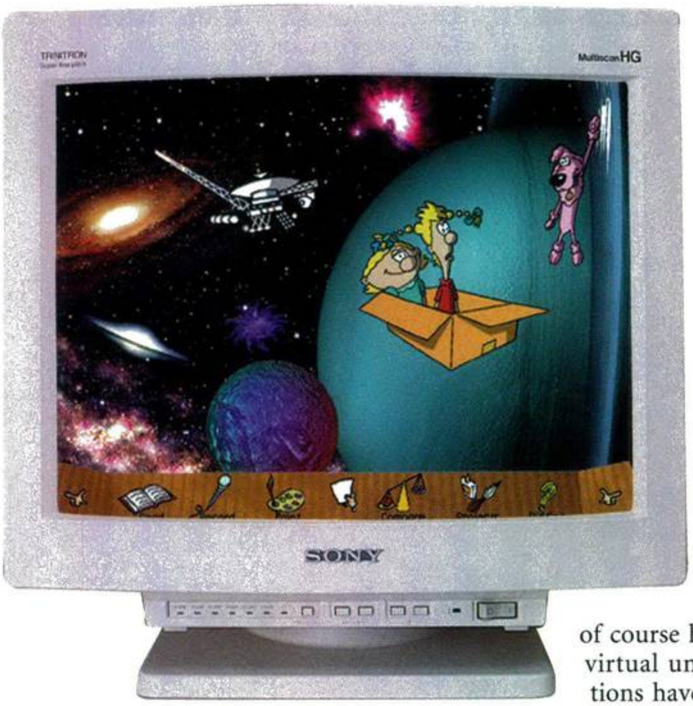
(continued from page 100)

BYTES

Connie & Bonnie's Birthday Blastoff

▶ "Why settle for the moon when you can give your kids nine planets, Orion's Belt, and a pink poodle?" In fact, *Connie & Bonnie's Birthday Blastoff*, the first in the Active Stories series from Active Arts, offers much more than that. Intended for children ages 6 to 10, this interactive CD-ROM adventure teaches kids about the solar system as they play. As Connie and Bonnie speed past Mars, kids learn what makes it red and how much they would weigh on its surface. Fun riddles are sprinkled throughout the program to let kids apply what they've learned. More than 100 in-depth "hot spots" woven through the story provide additional material, and kids can also explore their artistic abilities through the built-in coloring book and painting application, which lets them add the colors they choose to a black-and-white drawing on screen. There are also suggestions for 34 hands-on activities away from the computer, like using a flashlight and an apple to study eclipses. NASA videos and connect-the-dot constellations round out this impressive collection of attention-grabbing activities for your child. The program also plays as an audiobook on home and car stereos.



Active Arts, Inc., 610 SW Broadway, Suite 500, Portland, OR 97205; phone, (503) 228-8000; fax, (503) 228-8080; e-mail, info@active-arts.com; website, www.active-arts.com. Price: $29.95. Minimum requirements — CD-ROM drive, color monitor; for PC: 486 or faster processor, 8 MB RAM; for Mac: 40 Mhz or faster processor, 16 MB RAM.

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▶ In celebration of the 40th anniversary of Sputnik, the Ultimax Group has released an up-to-date version of their 1994 Soviet space program. *Russians in Space* is a multi-media CD-ROM containing text and video footage never before widely available in the United States. Just a few clicks of the mouse bring the information you crave up on your screen.

The program has four major categories: Personalia, Programs, Technology, and Basics. Personalia, explains the narrator, deals with what is "undoubtedly the most important factor in space exploration: the people who made our breakthrough into the universe possible." The giants of cosmautics, including Konstantin Tsiolkovshy and Sergei Korolyov, are of course highlighted, but so too are virtual unknowns whose contributions have proven invaluable. Some entries include narrated video clips and are marked by a video camera icon. Others have written text accompanied by photographs, offering brief but informative biographies.

The Programs category provides a history of Russian research programs. The Technology category provides an in-depth examination of the space hardware, and the Basics category offers a mini-encyclopedia of facts and general information about space exploration.

Ultimax Group, 112 Mason Lane, Oak Ridge, TN 37830-8631; phone, (423) 483-7097, (800) ULTIMAX; fax, (423) 483-6317; e-mail, robot@ultimax.com; website, http:/www.catalog.com/ultimax. Price: $25 plus shipping and handling. Minimum requirements — 4 MB RAM, CD-ROM drive; for PC: 386SX or higher processor; Windows 3.1, 95, or NT; SVGA graphic card; sound card; for Mac: 68030 or higher processor, System 7.0 or higher, 256-color monitor or better.

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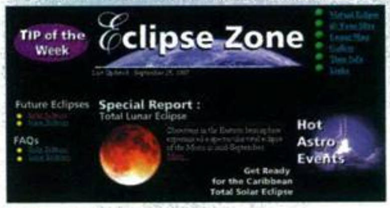

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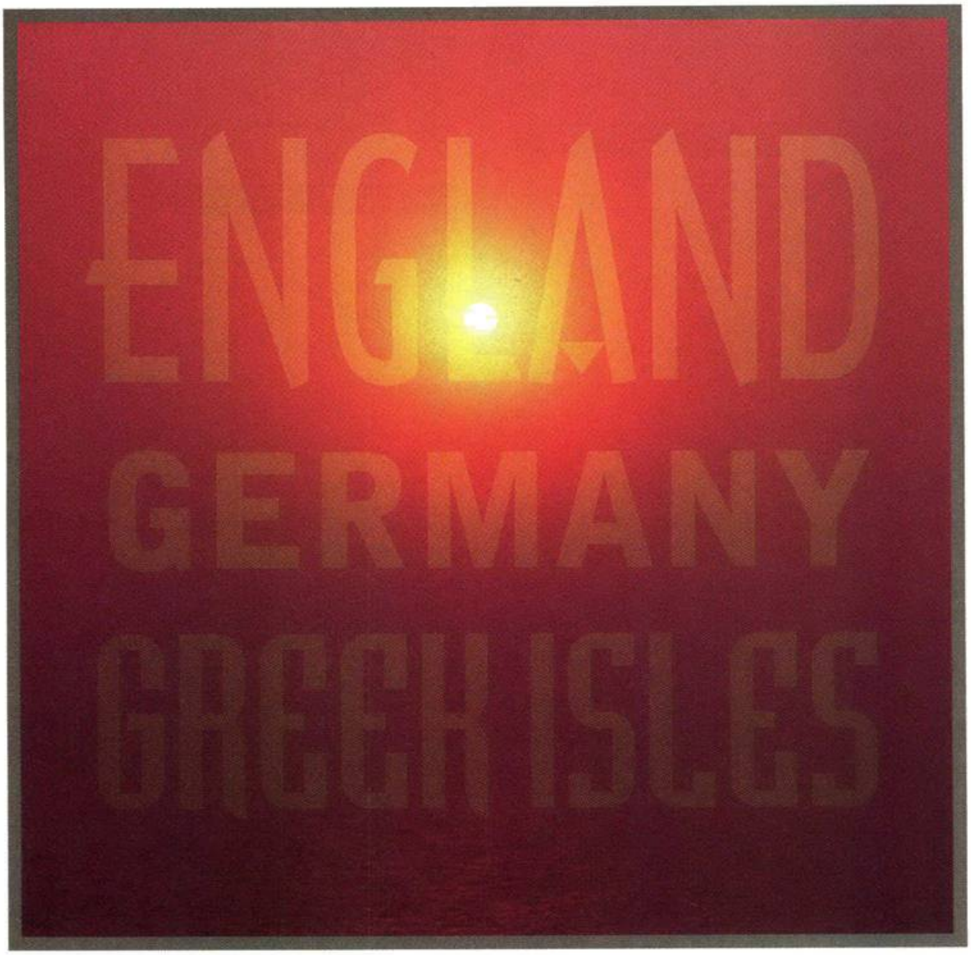

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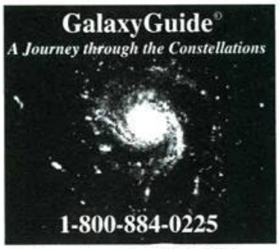

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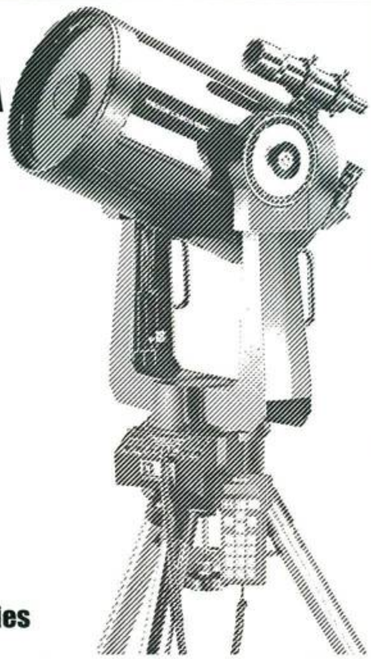

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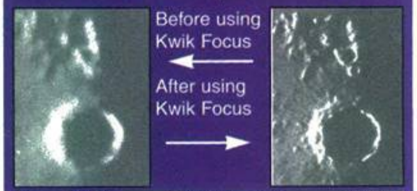

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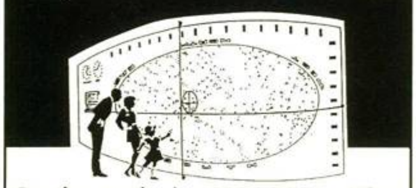

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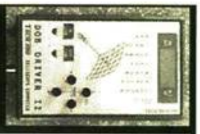

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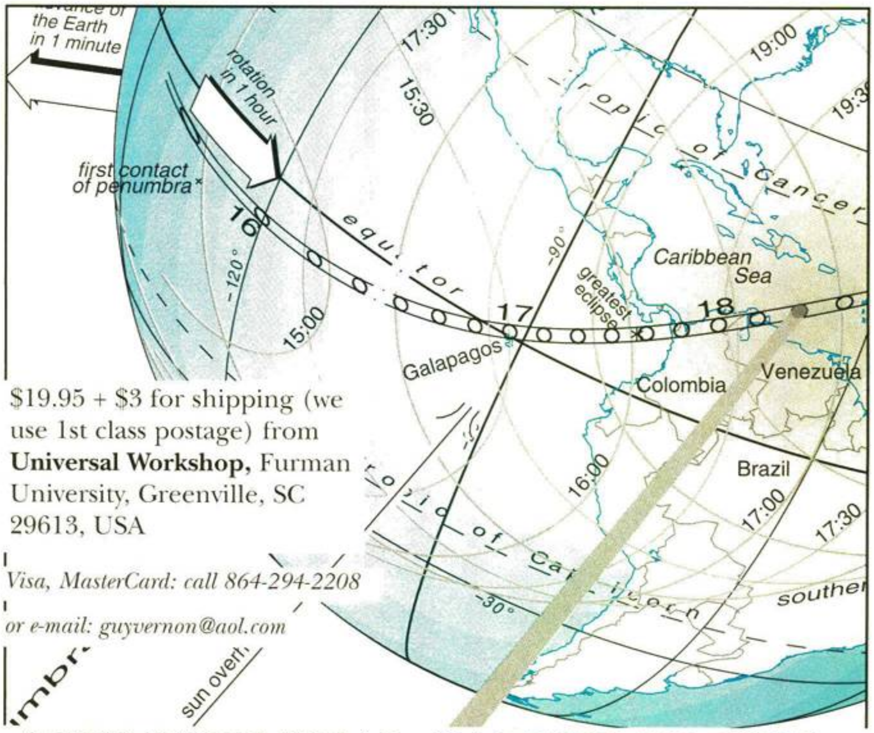

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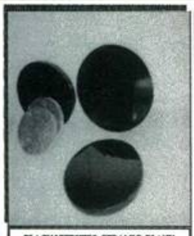

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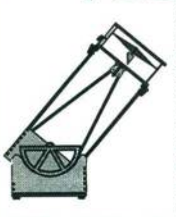

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Viewing a solar eclipse is a peak experience in the life of an astronomer – amateur and professional alike. Some of the most interesting letters we receive in our editorial offices are from readers who've traveled to exotic locales and experienced this celestial phenomenon.

So . . . *Astronomy* is hosting a cruise to view the eclipse taking place in the Caribbean from February 21–28. Several members of our editorial staff will be on board for evening stargazing sessions, lectures, and slide presentations. Special off-ship, day excursions are also planned.

Join us for this spectacular sky show.

John Hicks

Palm trees and telescopes silhouetted against the evening sky . . . a little bit of heaven on Earth for astronomers.

JANUARY 6–10
191st Meeting of the American Astronomical Society

▶ Washington Hilton and Towers, Washington, DC. Speakers include NASA Administrator Daniel Goldin and Vice President Al Gore. For registration information contact International Conference Management, 4709 Montgomery Lane, First Floor, Bethesda, MD 20814; (301) 913-9338, ext. 308; fax, (301) 913-5452; e-mail, aas98@conference.com; website, http://www.aas.org. AAS Executive Office, (202) 328-2010.

JANUARY 26–FEBRUARY 1
Winter Star Party

▶ West Summerland Key, Florida Keys. Sponsored by the Southern Cross Astronomical Society. Contact Mike Barrs or Therese Rubenstein at 3403 Poinciana Avenue, Miami, FL 33133; (305) 441-2428; e-mail, wsp@scas.org; website, http://www.scas.org/wsp.html. For information about accommodations call (800) FLA-KEYS.

JANUARY 29–FEBRUARY 1
The Orange Blossom Special Star Party

▶ Hickory Hill Observing Complex, near Brooksville, Florida. Sponsored by the St. Petersburg Astronomy Club. Contact Dennis and Ellen Farr, 8811 West Broad Street, Tampa, FL 33615; (813) 884-9111.

FEBRUARY 21–28
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FEBRUARY 26–MARCH 1
Highlands Stargaze

▶ Nine Mile Grade Campground, Sebring, Florida. Contact Richard Lindblom, 2130 Gresham Street, Sebring, FL 33872; e-mail, lindblom@ct.net; website, http://www.cris.com/~Lindblom/Index.shtml.

MARCH 7
Wagman Winterfest

▶ Nicholas E. Wagman Observatory, Mahaffey Road, Deer Lakes Regional Park, Russellton, Pennsylvania. Free. Contact Pete Zapadka, (412) 224-2510; e-mail, pzapadka@fyi.net; website, http://trfn.clpgh.org/orgs/aaap.

MARCH 16–20
Lunar and Planetary Science Conference

▶ NASA Johnson Space Center, Houston, Texas. Cosponsored by the Lunar and Planetary Institute and the NASA Johnson Space Center. Contact LeBecca Simmons, 118 Publications and Program Services Department, 3600 Bay Area Boulevard, Houston, TX 77058-1113; (281) 486-2158; e-mail, simmons@lpi.jsc.nasa.gov.

MARCH 21
Gathering at the Equinox

▶ Museum of York County, 4621 Mt. Gallant Road, Rock Hill, South Carolina 29732. Sponsored by the Museum of York County and the Carolina Skygazers. For information send a SASE to Barbara Reynolds, Settlemyre Planetarium at the above address; website, http://web.cetlink.net~btcrook/GATE.htm.

MARCH 26–29
Peach State Star Gaze

▶ Camp McIntosh, Indian Springs State Park, Jackson, Georgia. Sponsored by the Atlanta Astronomy Club. Contact Ken Poshedly, 3440 Everson Bay Court, Snellville, GA 30278; (770) 979-9842; e-mail, ken.poshedly@mci2000.com.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or to tconley@astronomy.com.

NASA's Next Space Observatories
(page 46)

SIRTF's website, http://sirtf.jpl.nasa.gov/sirtf/home.html; AXAF's website, http://xrtpub.harvard.edu/ pub.html

The New Astronomy, second edition, by Nigel Henbest and Michael Marten, (Cambridge University Press, 1996). This book is an excellent introduction to observations across the entire electromagnetic spectrum; includes information about satellite observations in the infrared and x-ray portions of the spectrum.

Sharpening the Stars (page 36)

The website http://www.cfht.hawaii.edu/manuals/aob/other-aosystems.html contains adaptive optics images and hot links to many other websites containing adaptive optics images.

Red Rover, Red Rover (page 42)

The website http://mpfwww.jpl.nasa.gov/default.html provides the latest images and information from Pathfinder and Sojourner.

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(Required by 39 USC 3685)

1. Publication title: ASTRONOMY
2. Publication No.: 531-350
3. Filing date: October 10, 1997
4. Issue frequency: monthly
5. Number of issues published annually: 12
6. Annual subscription price: $34.95
7. Complete mailing address of known office of publication: 21027 Crossroads Circle, Waukesha, WI 53186, Waukesha County. Telephone: 414-796-8776.
8. Complete mailing address of general business office of publisher: same
9. Publisher: Russell G. Larson, 21027 Crossroads Circle, Waukesha, WI 53186. Editor: Bonnie Gordon, same. Managing editor: David J. Eicher, same.
10. Owner: Kalmbach Publishing Co., 21027 Crossroads Circle, Waukesha, WI 53186; stockholders owning or holding 1 percent or more of total amount of stock are: Ruth H. O. Darragh, Rt. 8, Box 95, Harrison, AR 72601-8617; Harold Edmonson, 6021 N. Marmora Ave., Chicago, IL 60646; George A. Gloff, 9995 W. North Ave., Apt. 272, Wauwatosa, WI 53226; Elizabeth K. Grunden, 10926 Leaning Ash Ln., Houston, TX 77079; Linda H. Hanson, 22154 Harbor Rd., Barrington, IL 60010; Robert L. Hayden Jr., P. O. Box 1612, Waukesha, WI 53187-1612; Susan Fisher, 1152 N. Paseo de Golf, Green Valley, AZ 85614-3604; George F. Hirschmann Trust, 635 Glenridge Dr., Glenview, IL 60025; Estate of Margaret Anne Jenkins, Personal Representative: Mr. Lyle J. Vrhovnik, 2704 N. 117th St., Wauwatosa, WI 53222; Charles A. Kalmbach, 7435 N. Braeburn Ln., Glendale, WI 53209; Lois P. Kalmbach, 7435 N. Braeburn Ln., Glendale, WI 53209; Kalmbach Profit Sharing/401K Savings Plan & Trust, P. O. Box 1612, Waukesha, WI 53187-1612; James J. King, 3874 Quail Ridge Dr., Boynton Beach, FL 33436; Mahnke Family Trust, 10006 LaPlacita Dr., Rancho Cordova, CA 95670; Mahnke Family Limited Partnership, Dated July 8, 1996, 10006 LaPlacita Dr., Rancho Cordova, CA 95670; Dan Haley as Special Independent Trustee of the Mahnke Charitable Remainder Trust #1, Dated July 8, 1996, 2035 Hurley Way, Suite #250, Sacramento, CA 95825; Walter J. Mundschau, P. O. Box 1612, Waukesha, WI 53187-1612; Robelif, Inc., P. O. Box 3597, Reno, NV 89505; David M. Thornburgh Trust, 420 W. San Marino Dr., Miami Beach, FL 33139-1136.
11. Known bondholders, mortgagees and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities: N/A
12. Tax status (for completion by nonprofit organizations authorized to mail at special rates): N/A
13. Publication title: ASTRONOMY
14. Issue date for circulation data below: September 1997
15. Extent and nature of circulation:

	Average no. copies each issue during preceding 12 months	Actual no. copies of single issue published nearest to filing date
A. Total number of copies (net press run)	238,383	244,773
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G. Total distribution (sum of 15C and 15F)	177,763	177,052
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16. Publication of statement of ownership: Publication required. Printed in the January 1998 issue of this publication.
17. I certify that the statements made by me above are correct and complete. Gerald B. Boettcher, Vice President – Finance. Date: October 3, 1997

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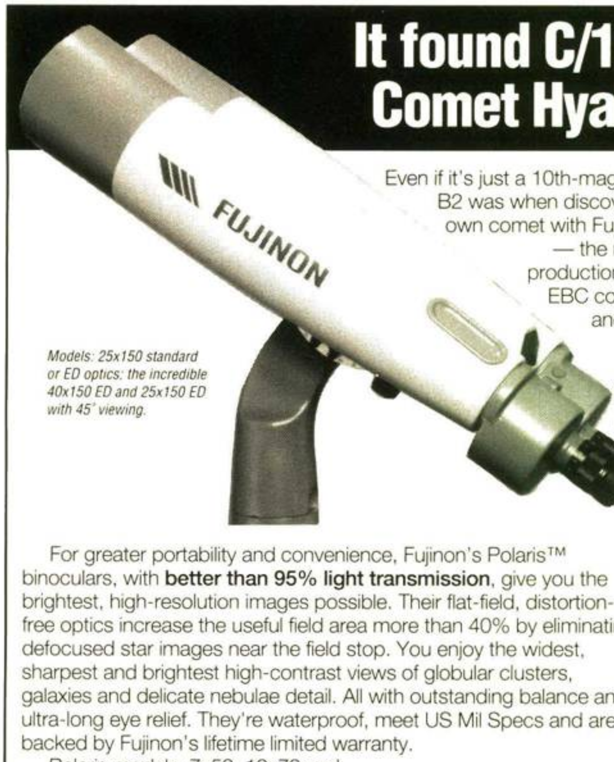

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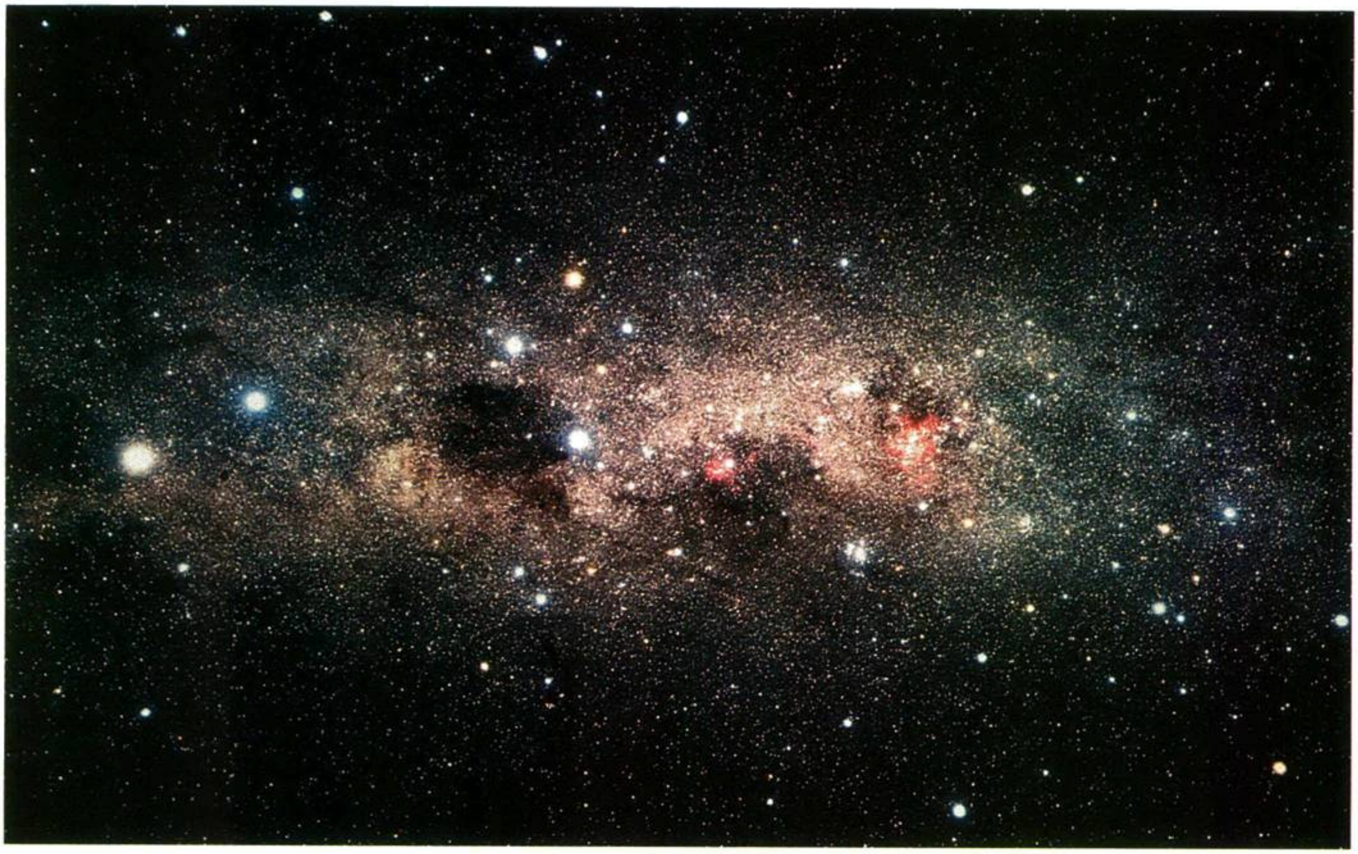


The Southern Cross Glistens in Crux

LUKE DODD

(55mm lens at f/4, hypered Fujicolor 400 film, composite of two 20-minute exposures)

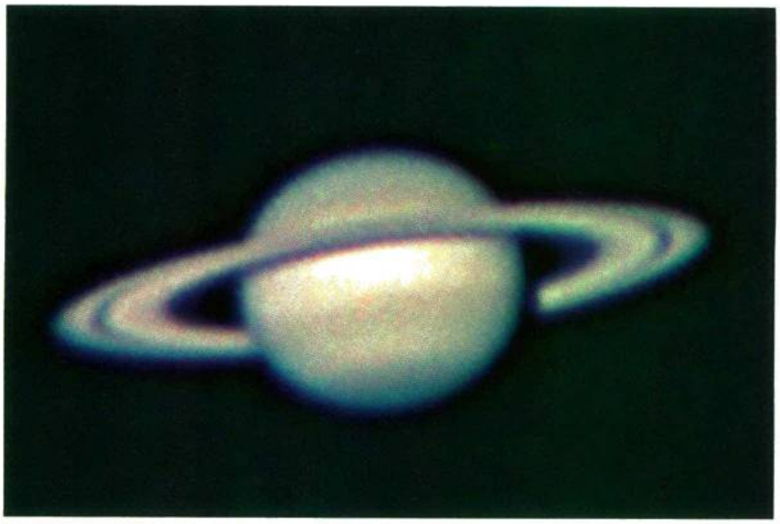
SOUTHERN ROMANCE

Sweet Southern Skies

An astronomer courts the Southern Hemisphere's magnificent skies.

▶ The gentle winds of the April autumn carry golden leaves to the ground. New Zealand's summer months are drawing to a close and so is my observing run. For nine months I have been lost in a sweet romance with the southern sky.

The pursuit was simple: to observe the southern heavens, especially areas not visible from my home in Colorado. A big square box held all my gear — two telescopes (a 12-inch and 36-inch), 20x120 binoculars,



The Ringed Planet

JACK NEWTON

(16-inch f/10 SCT at f/30, Pictor 1616XT CCD camera, composite of 10-minute red, 20-minute green, 20-minute blue exposures) a CCD camera, and the usual collection of astronomy paraphernalia (like books, charts, accessories, and computer). I set up camp at a remote site in the Wairarapa Valley on the North Island, where 7th-magnitude stars could regularly be spotted with the naked eye.

With volume two of *Uranometria 2000.0* as my trusty guide, I covered 13,000 square degrees of sky and logged close to 90 quality nights of observing in my logbook. The weather can be spiteful in New Zealand. Nonetheless, 3,000 objects revealed themselves.

My goal, to observe everything in *Uranometria* south, was set. Though the Magellanic Clouds, with their rich star clusters and ghostly nebulous structures, were captivating, I had to move on after logging 300 objects in order to stick to my observing plan. I didn't want to get caught up and observe only the widely known showpieces.

Through my 36-inch scope, the expansive Keyhole Nebula (NGC 3372) served up more than four square degrees of dark, intricate nebulosity. The globular Omega Centauri, almost 90° above the horizon, revealed innumerable stars resolved within its core that shone like diamonds. The vast Tarantula Nebula (NGC 2070) and thousands of stars in 47 Tucanae were magnificent. And no southern sky observer should miss a view of Kapteyn's star — a speeding 8.8-magnitude red dwarf, second only to Barnard's star in highest proper motion.

Perhaps the most spectacular vista from a southern vantage point is the Milky Way galactic bulge at the zenith. Our galaxy between Canis Major and Scorpius,

Sparkling Pleiades

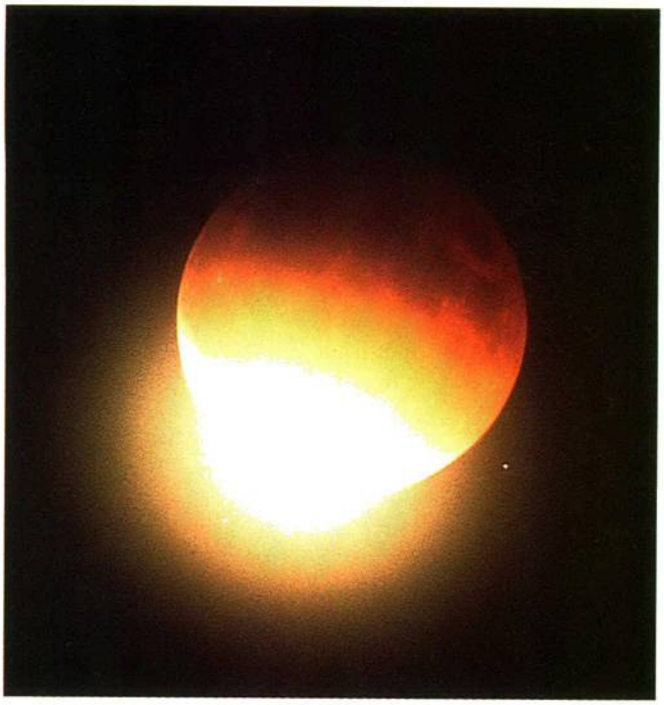
JASON WARE

(6-inch f/9 refractor, medium format camera, Fuji HG 400 film, composite of two 60-minute exposures)

A Lunar Eclipse Diamond Ring?

H. J. P. ARNOLD

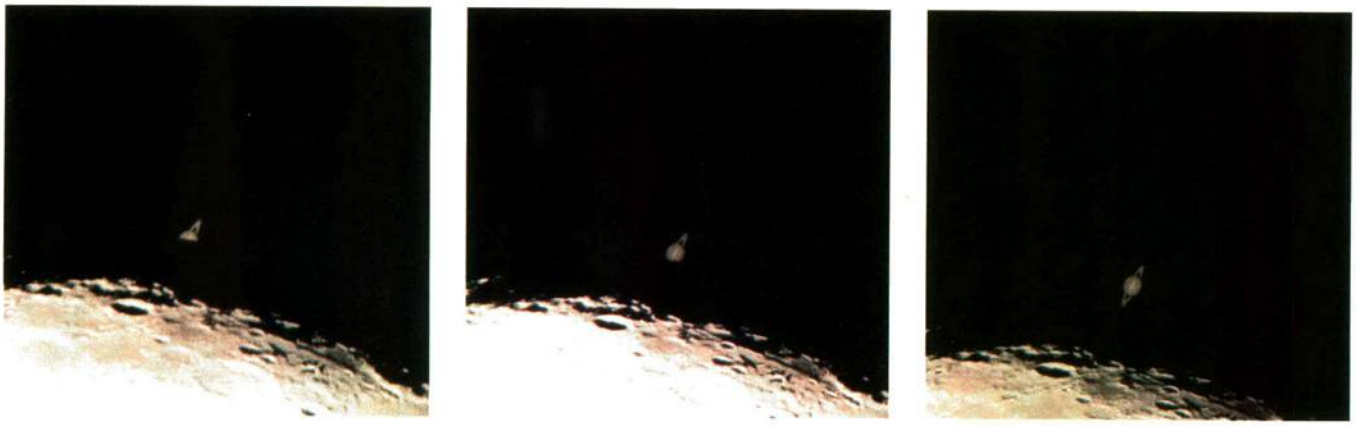
(1000mm lens at f/11, Fuji Provia 1600 film, 8-second exposure taken September 16, 1997)



The Moon Releases Saturn

CHRIS COOK

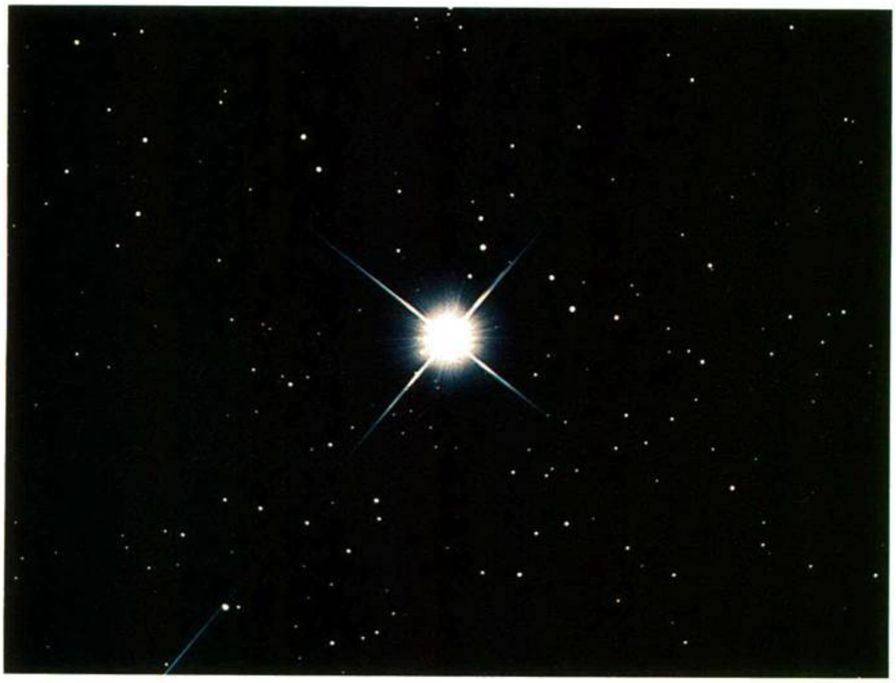
(8-inch SCT at f/95, Fujicolor Super HGV 400 film, three 1-second exposures taken September 18, 1997)



Bristling Sirius, the Dog Star

JOHN CHUMACK

(16-inch f/4.5 reflector, Ektar 100 film, 30-minute exposure)

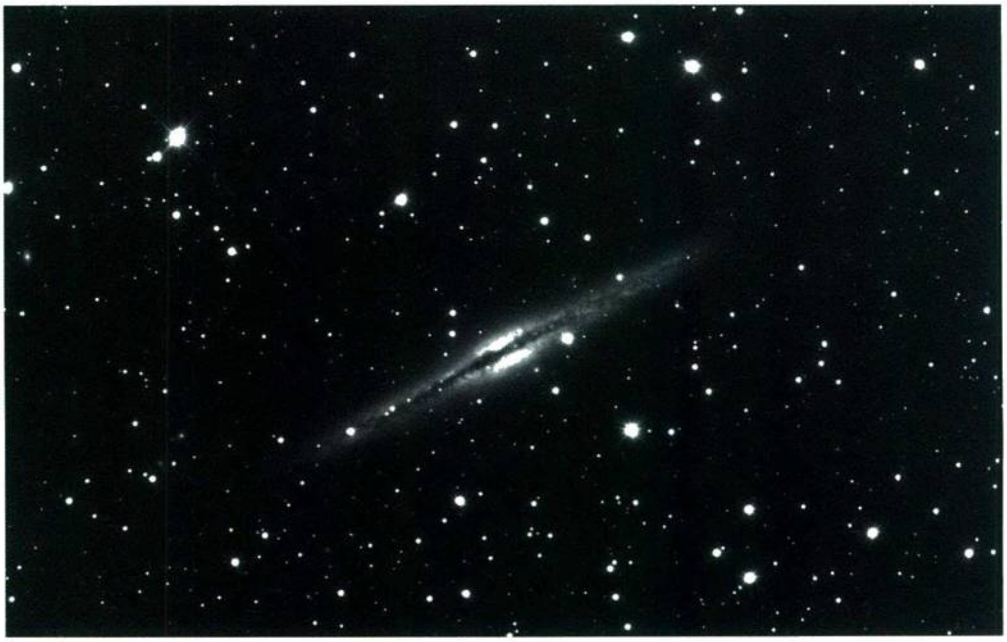


emblazoned with stars and nebulae, took my breath away. Its structure is amazing; its objects are endless.

Gazing on the southern sky one last time, I raised a toast. After witnessing nine glorious new moons under the southern heavens, I can say without hesitation that it is an experience every astronomer should have.

For those who've been there, you know just what I mean. For those who haven't, call your travel agents now — southern romance awaits you.

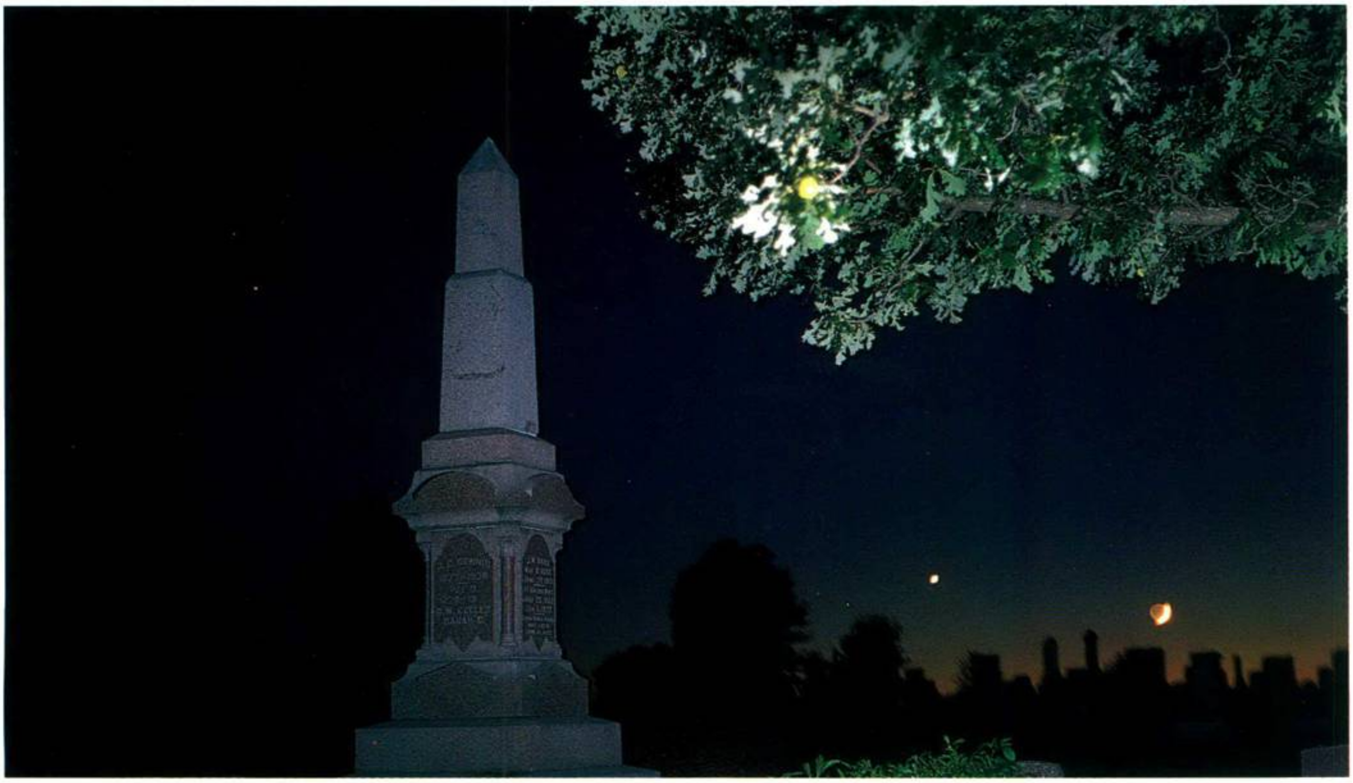
Bob Ross logged his 10,000th unique object during a southern observing run. He finished the Uranometria *North last August, and now has 36 pages left in the* Uranometria *South.*



NGC 891 in Andromeda

CHUCK VAUGHN

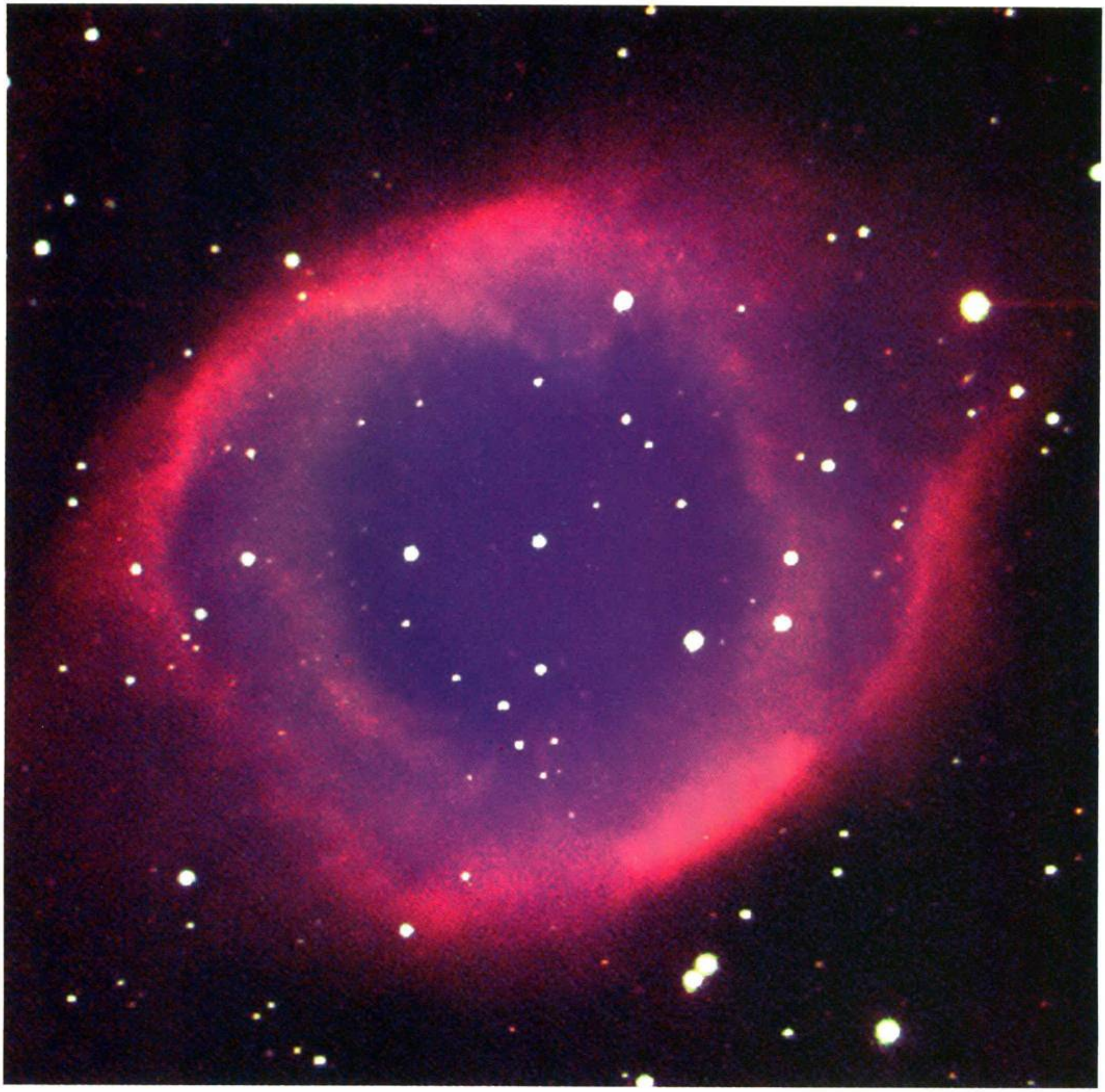
(12.5-inch f/9 Ritchey-Chretian scope, Tech Pan film, 100-minute exposure)

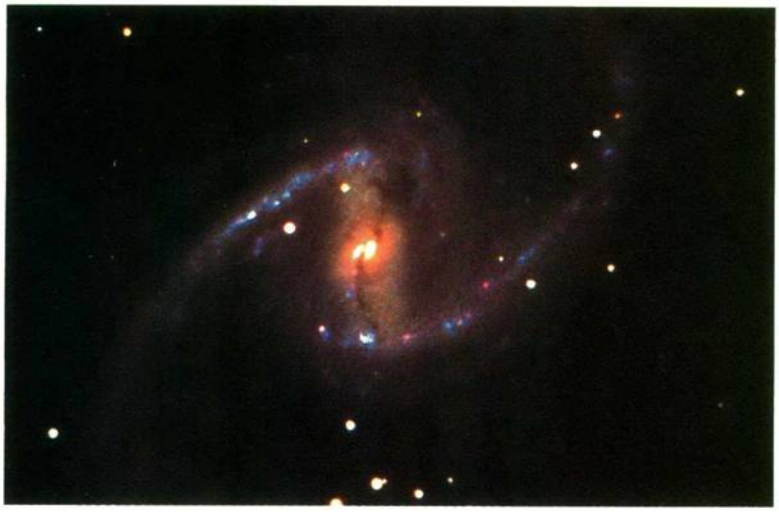


The Moon, Venus, Spica, Mars, and Zubenelgenubi

DOUGLAS C. ZUBENEL

(50mm lens at f/2, Fujichrome Professional Velvia film, 60-second exposure taken September 4, 1997)





The Helix Nebula (NGC 7293) in Aquarius

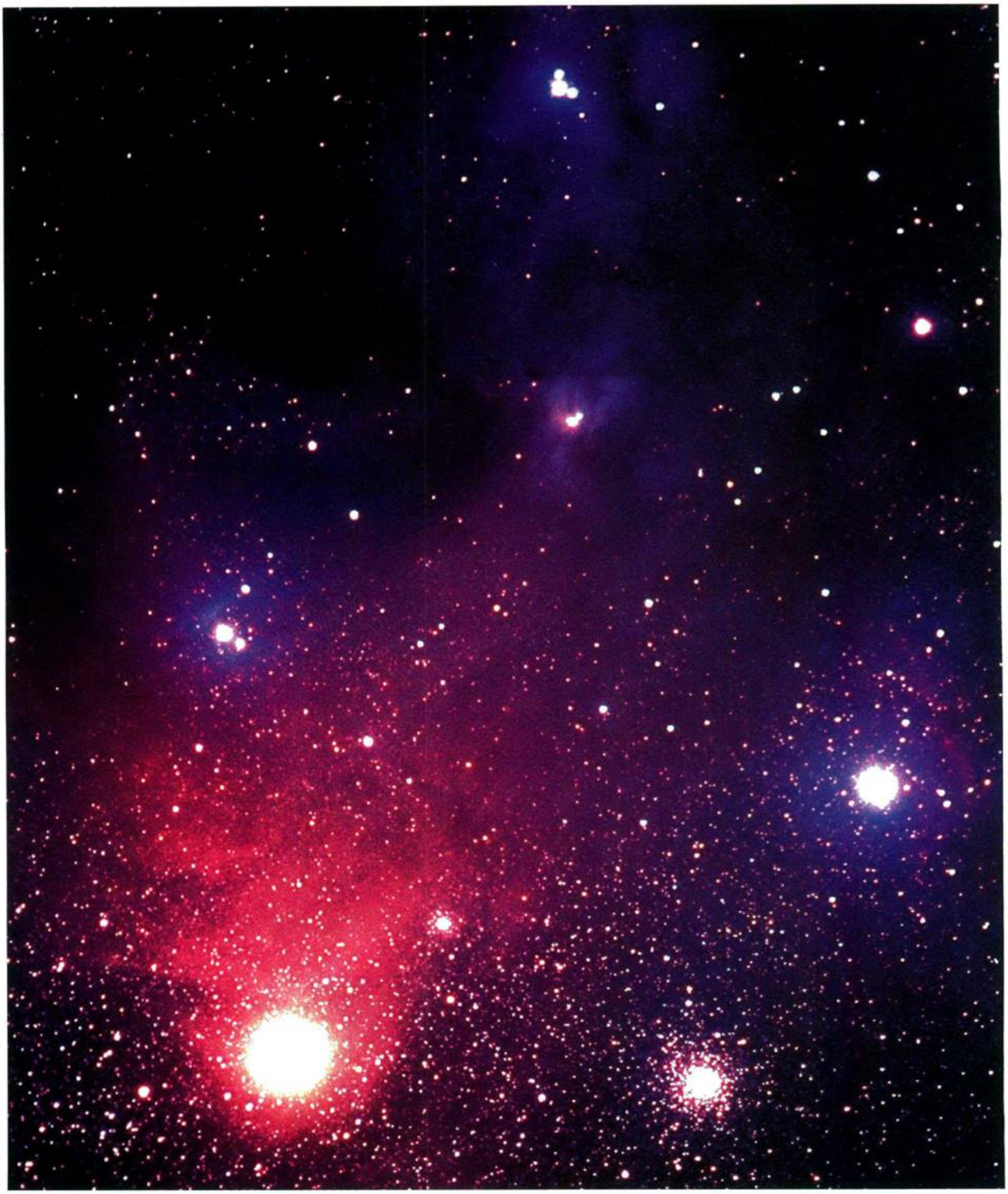
TIM PUCKETT

12-inch f/6.2 SCT, Apogee AP7 CCD camera, composite of three 300-second exposures through red, green, and blue filters)

Barred Spiral Galaxy NGC 1365

JAMES R. FOSTER

(11-inch f/11 SCT, hypered Fuji HG-400 film, composite of 103- and 60-minute exposures)



Cosmic Ornaments

FRED ESPENAK

(400mm f/3.5 lens, Fuji Super G 800 Plus, composite of two 25-minute exposures)

The heart of the Scorpion, Antares, is the brightest light in this line-up of stars, which resembles a celestial Christmas tree. Antares lies amidst the reddish and yellow gas and dust of IC 4606, a nebula about five light-years in diameter. West of Antares lies M4 (NGC 6121), one of the nearest and largest globular clusters, and forming a small triangle between the two is a much smaller globular, NGC 6144. Rho (ρ) Ophiuchi is the ornament at the top of this stellar display.

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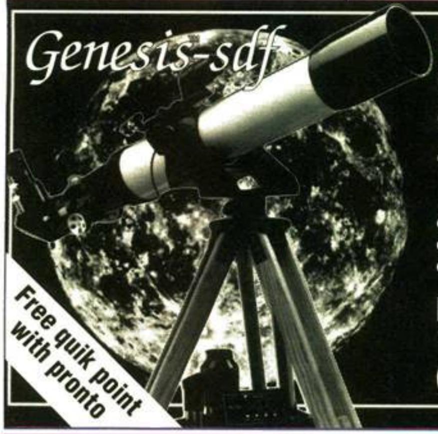

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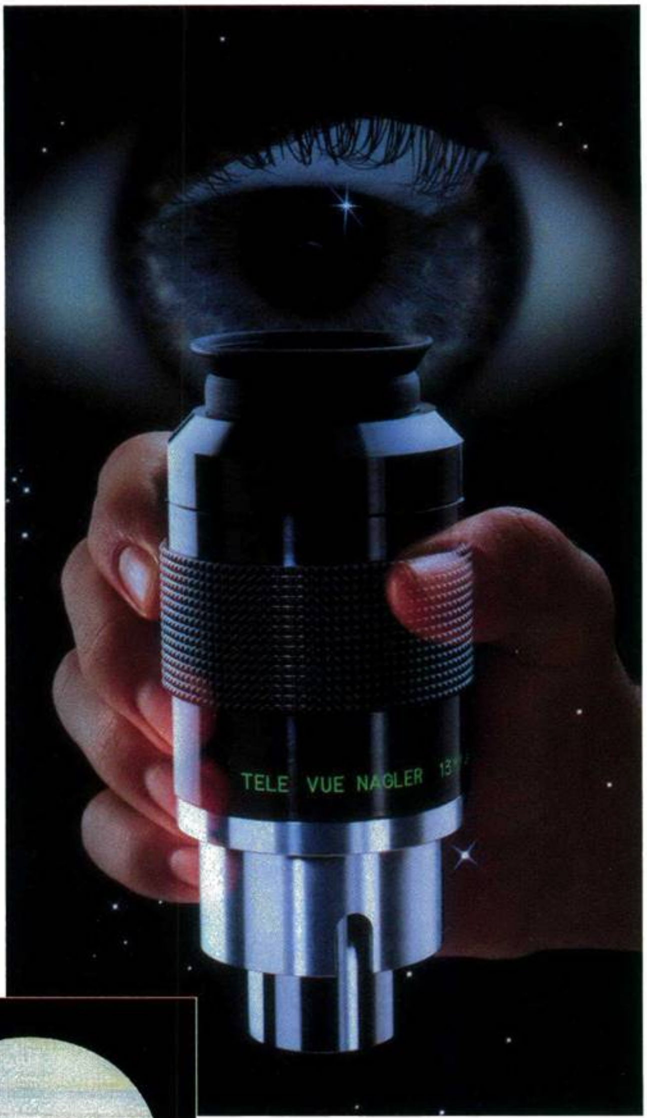
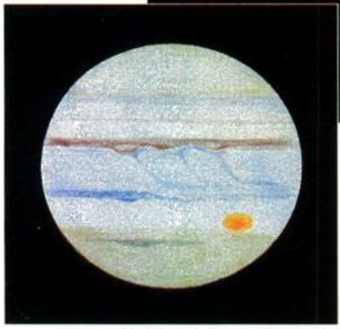
These eyepieces have given me my most rewarding hours spent at the telescope. *My main interest is in the planets which I draw and give lectures on at our local school and observatory. The observation of the planets requires painstaking hours spent at the eyepiece. The Naglers suit my purposes exactly.*




Drawn by Mr. Toohey with 12 N2

When the Type 2s were introduced onto the market I could not resist them. I purchased the 16mm and 12mm models. The 20mm seemed too large, heavy and costly, so I left it alone. These were the same reasons for not buying the 13mm (apart from the fact that by then I owned a 12mm Type 2). However, earlier this year, after years of looking through other people's 13mm and 20mm Naglers, I finally decided to take the plunge myself. ***So now I own a full set of Naglers*** *(including the wonderful 11mm which despite many offers, I will not part with).*

When I remember what eyepieces for the amateur market were like before the introduction of the Naglers (like looking down a drain pipe, or 60° fields, with astigmatism and severe edge of field aberrations), ***it is clear that your designs have taken us a quantum leap forward. No other eyepieces, in the Naglers' range of focal lengths, satisfy me now.***

Many of my fellow planetary observers say that conventional field eyepieces are sufficient. In a way they are right; good Plössls, for example, produce superb images. However, I believe the extra eye-relief, the huge field of the Naglers, coupled with marvellous image correction and the impression that ***the telescope simply gets out of the way,*** *all add up to a delightful psychological difference when using the Naglers. One feels more involved, more present to what one is viewing.*

Over the years I have found that amateur astronomers can be fairly stubbourn people in somehow defending their choice of equipment. Next thing you know they upgrade what was once, in their view, the very best available. ***Only good products stand the test of time. For me, the Naglers are such a product.*** *Not only have they remained with me; I have kept buying more of them!*

To some extent, astronomy, and particularly amateur astronomy, is about emotion and the involvement of the imagination. ***I have to say that Nagler eyepieces have captured my imagination.*** *As well as giving pride of ownership, Naglers are immensely satisfying and a joy to use.*

The little instruction sheet that comes with the eyepieces says that you wish the user 'years of exciting viewing with these eyepieces, and welcome comments on your experiences with them.' So you asked for it. After a decade of superb images (many of which remain etched on my memory; most of which I have recorded on paper) I felt it timely to share my comments and to thank you for your contribution to amateur astronomy."

Yours Sincerely.
Christopher A Toohey

Christopher Toohey, Australia

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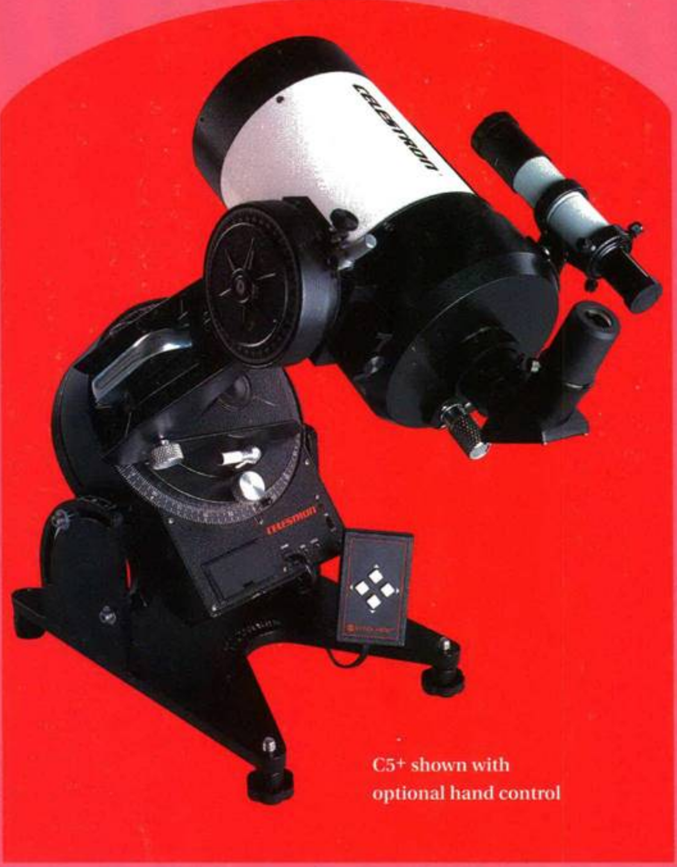
C5+ shown with optional hand control

C5+

- For astronomy on the go, the C5+ can't be beat. Due to its excellent Schmidt-Cassegrain design and careful crafting, this telescope is a serious, high performance instrument, and its compact size makes it totally portable.
- The optical system of the C5+ features Starbright® coatings. An *Astronomy* magazine review said, "the C5 I tested contained superb optics. At high powers, stars exhibited a clearly defined Airy disk surrounded by a bright first diffraction ring and several successively fainter outer rings. This was a telescope that demonstrated how well Schmidt-Cassegrain optics can perform and met Celestron's promise of diffraction limited optics."
- The C5+ features Celestron's legendary hand-figured, diffraction limited optical system for optical performance you can depend on. The reputation for excellence of this telescope is such that it was chosen by NASA, over all other competitive models, for several space shuttle missions.
- The DC electronics of the C5+ have a built-in drive controller, powered by a 9 volt alkaline battery. A comment from the *Sky & Telescope* review — "the digital electronics delivered a near perfect sidereal tracking rate."
- Standard equatorial wedge supplied with the C5+ has a built-in bubble level and is adjustable from 0° to 90°.

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